# Transactions of The Institution of Mining Engineers

Edited by the Secretary

VOL. XXI.

1900-1901.

[*Frontispiece, Vol. xxi.*]

LORD ARMSTRONG, C.B., LL.D., D.C.L., F.R.S., ETC.

PRESIDENT OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, 1872-1875.

*Born on November 26th, 1810, and died on December 27th, 1900.*

# TRANSACTIONS

OF

# THE INSTITUTION

OF

# MINING ENGINEERS.

## VOL. XXI.—1900-1901.

EDITED BY M. WALTON BROWN, SECRETARY.

NEWCASTLE-UPON-TYNE: PUBLISHED BY THE INSTITUTION.

PRINTED BY ANDREW REID & Co., LIMITED, NEWCASTLE-UPON-TYNE.
1903.

ADVERTIZEMENT.

The Institution, as a body, is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution or of the Federated Institutes.

# CONTENTS OF VOL. XXI.



## GENERAL MEETINGS.

THE INSTITUTION OF MINING ENGINEERS.

THE INSTITUTION OF MINING ENGINEERS.—*Continued.*



CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.



MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

THE MINING INSTITUTE OF SCOTLAND.



THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—*Continued.*



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NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.



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SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.



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APPENDICES.

APPENDICES.—*Continued.* PAGE.



LIST OF PLATES:—



ANY PUBLICATION OF A FEDERATED INSTITUTE MAY BE PLACED AT THE END OF THE VOLUME, *i.e.*, "ANNUAL REPORT," "LIST OF MEMBERS," ETC.

# THE INSTITUTION OF MINING ENGINEERS.

## OFFICERS, 1900-1901.

### Past-Presidents (*ex-officio*).

Mr. W. N. Atkinson, H.M. Inspector of Mines, Barlaston, Stoke-upon-Trent.
Mr. George Lewis, Albert Street, Derby.
Mr. J. A. Longden, Stanton-by-Dale, near Nottingham.
Mr. George A. Mitchell, 5, West Regent Street, Glasgow.
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Sir WILLIAM THOMAS LEWIS, Bart., Mardy, Aberdare.

### Vice-Presidents.

* Deceased.

Mr. Thomas Forster Brown, Springfort, Stoke Bishop, Bristol.
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Mr. George May, The Harton Collieries, South Shields.
*Mr. Frank N. Wardell, H.M. Inspector of Mines, Wath-upon-Dearne, near Rotherham.
Mr. J. G. Weeks, Bedlington, R.S.O., Northumberland.
Mr. R. S. Williamson, Cannock Wood House, Hednesford, Staffordshire.

### Council.

* Deceased.

Mr. Fred. R. Atkinson, Shottle Hall, near Derby.
Mr. J. B. Atkinson, H.M. Inspector of Mines, 2, Devonshire Terrace, Newcastle-upon-Tyne.
Mr. Emerson Bainbridge, 4, Whitehall Court, London, S.W.
Mr. James Barrowman, Staneacre, Hamilton, N.B.
Mr. John Batey, St. Edmunds, Coleford, Bath.
*Mr. W. Beattie-Scott, H.M. Inspector of Mines, Park Avenue, Handsworth, near Birmingham.
Sir Lowthian Bell, Bart., Rounton Grange, Northallerton.
Mr. T. W. Benson, 24, Grey Street, Newcastle-upon-Tyne.
Mr. G. J. Binns, Duffield House, Duffield, Derby.
Mr. M. Walton Brown, 10, Lambton Road, Newcastle-upon-Tyne.
Mr. H. M. Cadell, Grange, Bo'ness, R.S.O., Linlithgowshire.

Mr. William Henry Chambers, Conisborough, Rotherham.
Mr. A. G. Charleton, 5, Avonmore Road, Kensington, London, W.
Mr. G. E. Coke, 65, Station Street, Nottingham.
Sir David Dale, Bart., West Lodge, Darlington.
Mr. Thomas Douglas, The Garth, Darlington.
Mr. H. St. John Durnford, Featherstone, Pontefract.
Mr. T. E. Forster, 3, Eldon Square, Newcastle-upon-Tyne.
Mr. W. E Garforth, Snydale Hall, near Pontefract.
Mr. Charles D. Geddes, 21, Young Street, Edinburgh.
Mr. John Gemmell, 10, St. Andrew Square, Edinburgh.
Mr. Reginald Guthrie, Neville Hall, Newcastle-upon-Tyne.
Mr. James Hamilton, 208, St. Vincent Street, Glasgow.
Mr. James Hastie, Greenfield Colliery, Hamilton, N.B.
Mr. W. J. Hayward, West Bromwich.
Mr. James A. Hood, Rosewell, Mid-Lothian, N.B.
Mr. Philip Kirkup, Leafield House, Birtley, R.S.O., Co. Durham.
Mr. C. C. Leach, Seghill Colliery, Northumberland.
Mr. G. Alfred Lewis, Albert Sreet, Derby.
Mr. Edward Lindley, Eastwood, Nottingham.
Mr. Henry Louis, 11, Windsor Terrace, Newcastle-upon-Tyne.
Mr. M. H. Mills, Sherwood Hall, Mansfield.
Mr. T. W. H. Mitchell, Mining Offices, Regent Street, Barnsley.
Mr. John Nevin, Littlemoor House, Mirfield.
Mr. Henry Palmer, Medomsley, R.S.O., Co. Durham.
Mr. J. M. Ronaldson, H.M. Inspector of Mines, 44, Athole Gardens, Glasgow.
Mr. F. R. Simpson, Hedgefield House, Blaydon-upon-Tyne.
Mr. J. B. Simpson, Bradley Hall, Wylam-upon-Tyne.
Mr. Alexander Smith, 3, Newhall Street, Birmingham.
*Mr. John Strick, Bar Hill, Madeley, Staffordshire.
Mr. Edward B. Wain, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
Sir Thomas Wrightson, Bart., Stockton-upon-Tees.

## Auditors.

Messrs. John G. Benson & Son, Newcastle-upon-Tyne.

## Treasurers.

Messrs. Lambton & Company, The Bank, Newcastle-upon-Tyne.

## Secretary.

Mr. M. Walton Brown, Neville Hall, Newcastle-upon-Tyne.

# THE INSTITUTION OF MINING ENGINEERS.

FOUNDED JULY 1ST, 1889.

## BYE-LAWS

*As revised at Council Meeting held on May 29th, 1902.*

### I.—CONSTITUTION.

1.—The Institution of Mining Engineers shall consist of all or any of the societies interested in the advancement of mining, metallurgy, engineering and their allied industries, who shall from time to time join together and adhere to the Bye-Laws.

2.—The Institution shall have for its objects—

(a) The advancement and encouragement of the sciences of mining, metallurgy, engineering, and their allied industries.

(b) The interchange of opinions, by the reading of communications from members and others, and by discussions at general meetings, upon improvements in mining, metallurgy, engineering, and their allied industries.

(c) The publication of original communications, discussions, and other papers connected with the objects of the Institution.

(d) The purchase and disposal of real and personal property for such objects.

(e) The performance of all things connected with or leading to the purpose of such objects.

3.—The offices of the Institution shall be in Newcastle-upon-Tyne, or such other place as shall be from time to time determined by resolution of the Council.

4.—The year of the Institution shall end on July 31st in every year.

5.—The affairs and business of the Institution shall be managed and controlled by the Council.

### II.—MEMBERSHIP.

6.—The original adherents or founders are as follows:—

(a) Chesterfield and Midland Counties Institution of Engineers, Chesterfield.

(b) Midland Institute of Mining, Civil and Mechanical Engineers, Barnsley.

(c) North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

(d) South Staffordshire and East Worcestershire Institute of Mining Engineers, Birmingham.

7.—Written applications from societies to enter the Institution shall be made to the Council, by the President of the applying society, who shall furnish any information that may be desired by the Council.

8.—A.—If desired by the Council, any of the Federated Institutes shall revise their Bye-Laws, in order that their members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students, and section B following shall be a model Bye-Law to be adopted by any society when so desired by the Council.

B.—"The members shall consist of Ordinary Members, Associate Members and Honorary Members, with Associates and Students:—

(a) Each Ordinary Member shall be more than twenty-three years of age, have been regularly educated as a mining, metallurgical, or mechanical engineer, or in some other branch of engineering, according to the usual routine of pupilage, and have had subsequent employment for at least two years in some responsible situation as an engineer; or if he has not undergone the usual routine of pupilage, he must have been employed or have practised as an engineer for at least five years.

(b) Each Associate Member shall be a person connected with or interested in mining, metallurgy, or engineering, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering.
(c) Each Honorary Member shall be a person who has distinguished himself by his literary or scientific attainments, or who may have made important communications to any of the Federated Institutes.
(d) Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.
(e) Students shall be persons who are qualifying themselves for the profession of mining, metallurgical, or mechanical engineering, or other branch of engineering, and such persons may continue Students until they attain the age of twenty-five years."

9.—The Ordinary Members, Associate Members and Honorary Members, Associates and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

10.—The members of any Federated Institute, whose payments to the Institution are in arrear, shall not receive the publications and other privileges of the Institution.

11.—After explanations have been asked by the President from any Federated Institute, whose payments are in arrear, and have not been paid within one month after written application by the Secretary, the Council may decide upon its suspension or expulsion from the Institution; but such suspension or expulsion shall only be decided at a meeting attended by at least two-thirds of the members of the Council by a majority of three-fourths of the members present.

### III.—Subscriptions.

12.—Each of the Federated Institutes shall pay fifteen shillings per annum for each Ordinary Member, Associate Member, Honorary Member, Associate and Student, or such other sum, and in such instalment or instalments as may be determined from time to time by resolution or resolutions of the Council. Persons joining any of the Federated Institutes during the financial year of the Institution shall be entitled to all publications issued for that year, after his election is notified to the Secretary, and the instalment or instalments due on his behalf have been paid.

### IV.—Election of Officers and Council.

13.—The officers of the Institution, other than the Secretary and Treasurer, shall consist of Councillors elected annually prior to August in each year, by and out of the Ordinary Members and Associate Members of each Federated Institute, in the proportion of one Councillor per forty Ordinary Members or Associate Members thereof; of Vice-Presidents elected by and from the Council at their first meeting in each year on behalf of each Institute, in the proportion of one Vice-President per two hundred Ordinary Members or Associate Members thereof; and of a President elected by and from the Council at their first meeting in each year; who, with the Local Secretaries of each Federated Institute and the Secretary and Treasurer, shall form the Council. All Presidents on retiring from that office shall be *ex-officio* Vice-Presidents so long as they continue Ordinary Members or Associate Members of any of the Federated Institutes.

14.—In case of the decease, expulsion, or resignation of any officer or officers, the Council may, if they deem it requisite, fill up the vacant office or offices at their next meeting.

### V.—Duties of Officers and Council.

15.—The Council shall represent the Institution and shall act in its name, and shall make such calls upon the Federated Institutes as they may deem necessary, and shall transact all business and examine accounts, authorise payments and may invest or use the funds in such manner as they may from time to time think fit, in accordance with the objects and Bye-Laws of the Institution.

16.—The Council shall decide the question of the admission of any society, and may decree the suspension or expulsion of any Federated Institute for non-payment of subscriptions.

17.—The Council shall decide upon the publication of any communications.

18.—There shall be three ordinary meetings of the Council in each year, on the same day as, but prior to, the ordinary or annual general meetings of the members.

19.—A special meeting of the Council shall be called whenever the President may think fit, or upon a requisition to the Secretary signed by ten or more of its members, or by the President of any of the Federated Institutes. The business transacted at a special meeting of the Council shall be confined to that specified in the notice convening it.

20.—The meetings of the Council shall be called by circular letter, issued to all the members at least seven days previously, accompanied by an agenda-paper, stating the nature of the business to be transacted.

21.—The order in which business shall be taken at the ordinary and annual general meetings may be, from time to time, decided by the Council.

22.—The Council may communicate with the Government in cases of contemplated or existing legislation, of a character affecting the interests of mining, metallurgy, engineering, or their allied industries.

23.—The Council may appoint Committees, consisting of members of the Institution, for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institution.

24.—A Committee shall not have power or control over the funds of the Institution, beyond the amount voted for its use by the Council.

25.—Committees shall report to the Council, who shall act thereon and make use thereof as they may elect.

26.—The President shall take the chair at all meetings of the Institution, the Council, and Committees at which he may be present.

27.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institution. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any member of Council, or in case of their absence any Ordinary Member or Associate Member to take the chair at the meeting.

28.—At meetings of the Council six shall be a quorum.

29.—Every question shall be decided at the meetings of the Council by the votes of the majority of the members present. In case of equal voting, the President, or other member presiding in his absence, shall have a casting vote. Upon the request of two members, the vote upon any question shall be by ballot.

30.—The Secretary shall be appointed by and shall act under the direction and control of the Council. The duties and salary of the Secretary shall be fixed and varied from time to time at the will of the Council.

31.—The Secretary shall summon and attend all meetings of the Council, and the ordinary and annual general meetings of the Institution, and shall record the proceedings in the minute book. He shall direct the administrative and scientific publications of the Institution. He shall have charge of and conduct all correspondence relative to the business and proceedings of the Institution, and of all committees where necessary, and shall prepare and issue all circulars to the members.

32.—One and the same person may hold the office of Secretary and Treasurer.

33.—The Treasurer shall be appointed annually by the Council at their first meeting in each year. The income of the Institution shall be received by him, and shall be paid into Messrs. Lambton & Co.'s bank at Newcastle-upon-Tyne, or such other bank as may be determined from time to time by the Council.

34.—The Treasurer shall make all payments on behalf of the Institution, by cheques signed by two members of Council, the Treasurer and the Secretary after payments have been sanctioned by Council.

35.—The surplus funds may, after resolution of the Council, be invested in Government securities, in railway and other debenture shares such as are allowed for investment by trustees, in the purchase of land, or in the purchase, erection, alteration, or furnishing of buildings for the use of the Institution. All investments shall be made in the names of Trustees appointed by the Council.

36.—The accounts of the Treasurer and the financial statement of the Council shall be audited and examined by a chartered accountant, appointed by the Council at their first meeting in each year. The accountants' charges shall be paid out of the funds of the Institution.

37.—The minutes of the Council's proceedings shall at all times be open to the inspection of the Ordinary Members and Associate Members.

## VI.—General Meetings.

38.—An ordinary general meeting shall be held in February, May and Sepmember, unless otherwise determined by the Council; and the ordinary general meeting in the month of September shall be the annual general meeting at which a report of the proceedings, and an abstract of the accounts of the previous year ending July 31st, shall be presented by the Council. The ordinary general meeting in the month of May shall be held in London, at which the President may deliver an address.

39.—Invitations may be sent by the Secretary to any person whose presence at discussions shall be thought desirable by the Council, and persons so invited shall be permitted to read papers and take part in the proceedings and discussions.

40.—Discussion may be invited on any paper published by the Institution, at meetings of any of the Federated Institutes, at which the writer of the paper may be invited to attend. Such discussion, however, shall in all cases be submitted to the writer of the paper before publication, and he may append a reply at the end of the discussion.

## VII.—Publications.

41.—The publications may comprise:—

(a) Papers upon the working of mines, metallurgy, engineering, railways and the various allied industries.

(b) Papers on the management of industrial operations.

(c) Abstracts of foreign papers upon similar subjects.

(d) An abstract of the patents relating to mining and metallurgy, etc.

(e) Notes of questions of law concerning mines, manufactures, railways, etc.

42.—Each paper (with complete drawings, if any, to scale), to be read at any meeting of the Institution or of any of the Federated Institutes, shall be placed in the hands of the Secretary at least fourteen days before the date of the meeting at which the paper is to be read, and shall, subject to the approval of the Council, be printed, together with any discussion or remarks thereon.

43.—The Council may accept communications from persons who are not members of the Institution and allow them to be read at the ordinary or annual general meetings.

44.—No paper which has already been published (except as provided for in Bye-Law 41) shall appear in the publications of the Institution.

45.—A paper in course of publication cannot be withdrawn by the writer.

46.—Proofs of all papers and reports of discussions forwarded to any person for revision must be returned to the Secretary within seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

47.—The copyright of all papers accepted for printing by the Council shall become vested in the Institution, and such communications shall not be published for sale or otherwise without the written permission of the Council.

48.—Twenty copies of each paper and the accompanying discussion shall be presented to the writer free of cost. He may also obtain additional copies upon payment of the cost to the Secretary, by an application attached to his paper. These copies must be unaltered copies of the paper as appearing in the publication of the Institution, and the cover shall state that it is an "Excerpt from the Transactions of The Institution of Mining Engineers."

49.—The Federated Institutes may receive copies of their own portion of the publications in respect of such of their members as do not become members of the Institution, and shall pay 10s. per annum in respect of every copy so supplied; and similar copies for exchanges shall be paid for at cost price.

50.—The Local Secretary of each Federated Institute shall prepare and edit all papers and discussions of such Institute, and promptly forward them to the Secretary, who shall submit proofs to the Local Secretary before publication.

51.—A list of the members, with their last known addresses, shall be printed in the publications of the Institution.

52.—The publications of the Institution shall only be supplied to members, and no duplicate copies of any portion of the publications shall be issued to any member or Federated Institute unless by order of the Council.

53.—The annual volume or volumes of the publications may be sold, in the complete form only, at such prices as may be determined from time to time by the Council:—to non-members for not less than £3; and to members who are desirous of completing their sets of the publications, for not less than 15s.

54.—The Institution, as a body, is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution or of the Federated Institutes.

## VIII.—Medals and other Rewards.

55.—The Council, if they think fit in any year, may award a sum not exceeding sixty pounds, in the form of medals or other rewards, to the author or authors of papers published in the *Transactions*.

## IX.—Property.

56.—The capital fund shall consist of such amounts as shall from time to time be determined by resolution of the Council.

57.—The Institution may make use of the following receipts for its expenses:—

(*a*) The interest of its accumulated capital fund;

(*b*) The annual subscriptions; and

(*c*) Receipts of all other descriptions.

58.—The Institution may form a collection of papers, books and models.

59.—Societies or members who may have ceased their connexion with the Institution shall have no claim to participate in any of its properties.

60.—All donations to the Institution shall be acknowledged in the annual report of the Council.

## X.—Alteration of Bye-Laws.

61.—No alteration shall be made in the Bye-Laws of the Institution, except at a special meeting of the Council called for that purpose. and the particulars of every such alteration shall be announced at their previous meeting and inserted in the minutes, and shall be sent to all members of Council at least fourteen days previous to such special meeting, and such special meeting shall have power to adopt any modification of such proposed alteration of the Bye-Laws, subject to confirmation by the next ensuing Council meeting.

## THE INSTITUTION OF MINING ENGINEERS.

## SUBJECTS FOR PAPERS.

The Council of The Institution of Mining Engineers invite original communications on the subjects in the following list, together with other questions of interest to mining and metallurgical engineers.

Assaying.
Automatic coupling of mineral wagons.
Blowing out of coal and minerals *in situ*.
Boiler explosions.
Bore-holes and prospecting.
Boring against water and gases.
Brickmaking by machinery.
Brine-pumping.
Canals, inland navigation, and the canalization of rivers.
Coal-getting by machinery.
Coal-washing machinery.
Coke manufacture and recovery of bye-products.
Colliery leases, and limited liability companies.
Compound winding-engines.
Compressed-air as a motive-power.
Consumption of steam and water in engines.
Corrosive action of mine-water on pumps, etc.
Descriptions of coal-fields.
Diamond-mining.
Distillation of oil-shales.
Drift and placer-mining.
Duration of coal-fields of the world.
Electric mining lamps.
Electricity and its applications in mines.
Electro-metallurgy of copper, etc.
Engine-counters and speed-recorders.
Explosions in mines.
Explosives used in mines.
Faults and veins.
Fuels and fluxes.
Gas-producers, and gaseous fuel and illuminants.
Gas, oil and petroleum engines.
Geology and mineralogy.
Gold-recovery plant and processes.
Graphite: its mining and treatment.
Haulage in mines.
Industrial assurance.
Inspection of mines.
Laws of mining and other concessions.
Lead-smelting.
Light railways.
Lubricating value of grease and oils.
Lubrication of trams and tubs.
Maintenance of canals in mining districts.
Manufacture of fuel-briquettes.
Mechanical preparation of ores and minerals.
Mechanical ventilation of mines, and efficiency of the various classes of ventilators.
Metallurgy of gold, silver, iron, copper, lead, etc.
Mineral resources of colonies.
Mining and uses of arsenic, asbestos, bauxite, mercury, etc.
Natural gas, conveyance and uses.
Occurrence of mineral ores, etc.
Ore-sampling machines.
Petroleum-deposits.
Preservation of timber.
Prevention of over-winding.
Pumping machinery.
Pyrometers and their application.
Quarries and methods of quarrying.
Rectification of mineral oils.
Rock-drills.
Safety-lamps.
Salt-mining, etc.
Screening, sorting and cleaning of coal.
Shipping and discharge of coal-cargoes.
Sinking, coffering and tubbing of shafts.
Sleepers of cast-iron, steel and wood.
Smelting.
Spontaneous ignition of coal and coal-seams.
Stamp-milling.
Steam-condensation arrangements.
Steam-power plants.
Submarine coal-mining.
Subsidences caused by mining-operations.
Sulphur-mining.
Surface-arrangements of mines.
Surveying.
Tin-mining.
Transport on roads.
Tunnelling, methods and appliances.
Utilization of dust and refuse coal.
Utilization of sulphureous gases resulting from metallurgical processes.
Ventilation of coal-cargoes.
Ventilation of mines.
Water as a motive-power in mines.
Water-tube boilers.
Watering coal-dust.
Water-incrustations in boilers, pumps, etc.
Winding arrangements at mines.
Winning and working of mines at great depths.

For selected papers, the Council may award prizes. In making awards, no distinction is made between communications received from members of the Institution or others.

H. I. M.

# VICTORIA,

QUEEN OF THE UNITED KINGDOM OF

GREAT BRITAIN AND IRELAND,

AND EMPRESS OF INDIA.

BORN, MAY 24TH, 1819.

DIED, JANUARY 22ND, 1901.

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# TRANSACTIONS

OF

# THE INSTITUTION

OF

# MINING ENGINEERS.

## THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

Held in the Wood Memorial Hall, Newcastle-upon-Tyne,

February 9th, 1901.

Mr. J. G. WEEKS, President, in the Chair.

## DEATH OF HER MAJESTY QUEEN VICTORIA.

The President (Mr. J. G. Weeks) said that death had taken from them "The Most High, Most Mighty and Most Excellent Monarch, Queen Victoria." He need not attempt to enumerate the many virtues she had shewn during her record reign; but the sympathy which she had extended to those under her rule in periods of suspense and suffering had made her wellbeloved, and they in that district (most especially at the time of the Hartley accident in 1862) were deeply conscious of her solicitude. From the changes in the method of locomotion, the progress in engineering, and the discoveries in science that had taken place since 1837, Her Majesty's reign would rank as a record, beyond the mere fact of its duration. The present greatness of the British Empire had never been equalled, and they knew to what Her Majesty attributed the "Secret of England's Greatness." The Duke of Devonshire said that "there never was a character standing less in need of exaggeration," and a friend of his (the President's), of equal age with Her Majesty, wrote that

"She was one, no praise of whom could be extravagant." With testimonies such as these, all had felt deep and sincere sorrow at the Queen's death.

The Council had sent the following loyal and dutiful address to His Majesty King Edward the Seventh on the occasion of the demise of Her late Majesty, Queen Victoria, and of compliments and congratulations on his accession to the throne:—

## To the King's Most Excellent Majesty.

Most Gracious Sovereign,

The North of England Institute of Mining and Mechanical Engineers, Incorporated by Royal Charter in 1876, humbly beg to express to Your Majesty their profound grief and sorrow at the lamented death of Her Most Gracious Majesty Queen Victoria, which has caused a deep feeling of pain and sadness in Her Wide Dominions, and also throughout the World.

Whilst giving expression to their deepest sympathy and condolence with Your Majesty and all the Members of the Royal Family, they also humbly beg to convey to Your Majesty their sincere and zealous wishes for the happiness and prosperity of Your Majesty's Reign, and to assure Your Majesty of their deep devotion and loyalty to the Throne.

Witness our Hands and Seal the thirty-first day of January, 1901.

SEAL.

JOHN GEORGE WEEKS, President.

M. WALTON BROWN, Secretary.

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### THE LATE LORD ARMSTRONG, C.B.

The President (Mr. J. G. Weeks) said that Lord Armstrong was president of the Institute from 1872 to 1875. His inaugural address was worth studying, and it would be found that they had not profited by the very good advice which it contained. "There was no institution in the city of Newcastle-upon-Tyne or in the neighbourhood, worthy of support on religious, educational, or philanthropic grounds, which had not largely benefited

by his assistance. Among those who have made the nineteenth century remarkable in the history of the world for the wonderful advance of science and the richness of mechanical invention, posterity will venerate Lord Armstrong as one of the most famous and most illustrious; and his discoveries had made a new era in civilization."

The members were proud to have had so distinguished an engineer, as the late Lord Armstrong as one of their Presidents; and he moved that a vote of condolence be sent to Mr. W. A. Watson-Armstrong and family, conveying the sympathy of the members with them, in the loss which they had sustained by the death of their illustrious relative.

Mr. J. H. Merivale, in seconding the resolution, remarked that the deceased nobleman was an engineer of extraordinary talent, one of the greatest that we had had in Great Britain, and as the result of that talent he had accumulated a fortune, which he applied for the benefit of the district in which he lived.

The vote of condolence was unanimously adopted.

## THE LATE MR. GEORGE BAKER FORSTER.

The President (Mr. J. G. Weeks) moved that a vote of condolence be sent to Mrs. Forster and the family of the late Mr. G. B. Forster. He was wellknown to the members personally, and was identified with the Institute almost from its commencement. He was president from 1881 to 1884, and as a proof how unremitting he was in his attention to the interests of the Institute, it was stated that he was present at 19 out of 21 meetings held during his presidency. He took great interest in their discussions, and respecting his helpful and valuable services, he felt that he could not say enough.

Mr. R. Donald Bain (H.M. Inspector of Mines), in seconding the vote of condolence, stated that 30 years ago he served his apprenticeship under the late Mr. Forster's father, and a friendship sprang up then, which had been continued throughout his life. Mr. G. B. Forster had attained to great eminence in his profession, and was always willing to give his advice to those who sought it. The mining industry, not only of this

district, but throughout Great Britian, must deplore the death of so eminent an engineer, and a man of such excellent personal qualities.

Mr. A. L. Steavenson (Durham) also paid a tribute to the memory of Mr. G. B. Forster, whom he had probably known longer than any member present. He made his acquaintance in the forties, when he was reading with the vicar of Darlington, after that he went to Cambridge, and ultimately became a mining engineer. During the past 50 years, they had been the best of friends, and had had many talks about the affairs of the Institute. Mr. G. B. Forster maintained that it was the duty of all members to attend the meetings, even at some considerable inconvenience to themselves, and especially of the older members, in order that the younger men might have the benefit of their experience.

The vote of condolence was unanimously adopted.

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## THE LATE MR. THOMAS HEPPELL.

The President (Mr. J. G. Weeks) said that the late Mr. Thomas Heppell for many years had been actively connected with the Institute, and as a member of Council had helped it in every way which lay in his power. He moved that a vote of condolence and sympathy be forwarded to Mrs. Heppell.

Mr. W. C. Blackett seconded the resolution, which was unanimously adopted.

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The Secretary read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on January 26th and that day.

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The following gentlemen were elected, having been previously nominated:—

Members—

Mr. John W. Batey, Colliery Manager, Beech Grove, West Ryton-upon-Tyne.

Mr. Richard Henry Brown, Civil and Mining Engineer, Sydney Mines, Cape Breton, Nova Scotia, Canada.

Mr. John Colley, Colliery Manager, Green Mine, Indwe, Cape Colony, South Africa.

Mr. Edwin Collett Homersham, Mechanical Engineer, Sons of Gwalia Gold-mines, Leonora, Western Australia.

Mr. Axel Larsen, Civil Engineer, 128, Cambridge Street, London, S.W.

Mr. Arthur Henry Leech, Mining Engineer, 11, King Street, Wigan.

Mr. J. J. Prest, Civil Engineer, Easington, County Durham.

Mr. Robert Dobson Robinson, Colliery Manager, Tamworth Colliery Company, Tamworth, Warwickshire.

Mr. William Rutherford, junior, Assistant Manager, South Derwent Colliery, Annfield Plain, County Durham.

Mr. Antonio de Satrustegui, Mining Engineer, Barcelona, Spain.

Mr. William Brumwell Wilson, junior, Assistant Viewer, Wheatley Hill Colliery, Thornley, R.S.O., County Durham.

Mr. Harben Robert Young, Engineer, Henley Street, Westport, New Zealand.

Associate Members—

Mr. Arthur Cecil Broadbent, 39, Hyde Park Gate, London, S.W.

Mr. Harold Hastings Pavitt, Greymouth, New Zealand.

Associate—

Mr. Samuel George Coxon, Surveyor, Old Penshaw, Fence Houses, County Durham.

Students—

Mr. George Dixon, Mining Apprentice, Seghill Colliery, Seghill, Northumberland.

Mr. William Clouston Jay, Articled Pupil, Greymouth, New Zealand.

Mr. Walter Jones, Mining Pupil, Thornley Colliery Office, Thornley, R.S.O., County Durham.

Mr. Donald Locke, Student of Metallurgy, Anglo-American Club, Freiberg in Saxony, Germany.

Mr. Reginald Samuel Moncrieff Logan, Mining Student, Throckley Colliery, Newburn, R.S.O., Northumberland.

Mr. Donald MacGregor, Mining Apprentice, Seghill Colliery, Seghill, Northumberland.

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## DISCUSSION ON MESSRS. JOHN GREGORY AND JOHN T. STOBBS' "NOTES ON THE KŒPE SYSTEM OF WINDING."*

Mr. A. L. Steavenson (Durham) suggested that additional danger was incurred by passing a second rope down the shaft. He had introduced a scroll-drum in the case of a heavy lift, but he thought that there might be more liability to accident.

Mr. F. R. Simpson (Ryton) said that when the Kœpe system of winding was introduced in Staffordshire considerable trouble

* *Trans. Inst. M.E.*, 1899, vol. xviii., page 450.

was experienced, owing to the winding-rope slipping on the driving-pulley; but eventually, as stated in the paper, it was found that the difficulty could be remedied by placing a hemp rope in the tread of the pulley.

Prof. HENRY LOUIS (Durham College of Science) asked whether any special method was adopted of recapping the ropes from time to time. Like other systems in which there was a rope underneath the cage, the weakest part, the cap, had to bear the maximum strain, namely, the entire weight of the balance-rope, in addition to that of the loaded cage.

The PRESIDENT said the No. 3 pit at Sneyd colliery was 1,110 feet deep, and at their maximum speed of winding, as much coal had been drawn in an hour as would represent 792 tons in an 8 hours' day or 99 tons per hour. The method of changing the ropes was described in the paper, and the lengthening of the rope was adjusted by interposing about 3½ feet of large-link chain, between the capping and one of the cages, and the length of the chain was reduced, link by link, as necessity arose.

Prof. LOUIS said that his question was whether a length was taken off the end of the rope, and the rope recapped, as was done with ordinary winding-ropes every few months.

Mr. W. C. BLACKETT (Durham) said that the Kœpe system of winding had doubtless to contend with the difficulty of subjecting the weakest part—the capping of the rope—to the full strain of the load, plus the weight of the rope which was hung below the cage. Some few years ago, he had an ordinary form of socket prepared, and experiments shewed that only a comparatively small portion of the factor of safety of the rope was found in the capping—the ordinary factor of 10 being reduced to 5 or 6. He had designed another socket, which when subjected to the same tests, was able to sustain the breaking strain, within 15 or 20 per cent. Indeed with the new form of rope-socket, he could break the rope, while with the old form of socket, the rope-end was invariably drawn out.

Mr. JOHN GREGORY wrote that the additional dangers suggested by Mr. A. L. Steavenson and Prof. H. Louis were entitled

to serious consideration, but the result of practical working of the system for 18 years proved that such dangers were more apparent than real. The balance rope, instead o creating additional risk, had a steadying effect on the cages -and the "tacklers" being always taut, the capping of the rope was never subjected, on starting, to a violent shock, which would cause infinitely more damage thereto than the gradually increasing load which it was called upon to bear when a tail rope was used. During the whole of the time since the adoption of the Kœpe system, there had not been the slightest difficulty with the capping, and no sign of weakness in this part of the rope had ever developed.

The capping is similar to that employed at the other pits of the Sneyd collieries, and in view of the interest attached to this important part of the system it will perhaps be useful to describe it in detail. The rope is tightly wrapped with thin wire, 2½ feet from the end, and the loose end unstranded; one-third of the wires are bent back singly, and then a length of about 10 inches is cut off the remainder; half of these are next bent back and another length of 10 inches is cut off the remaining wires; which are finally bent back. The rope-end is then tightly wrapped with a single layer of tarred cord, and the capping, 3½ feet long, is secured by three rings driven tight, and by three or four rivets passing through the rope. Although the capping had not been renewed at regular intervals, it was done frequently, and indeed had been rendered necessary by the gradual stretching of the rope, while working.

The slipping of the winding rope referred to by Mr. F. R. Simpson did not occur at Sneyd Colliery; and, in that case, nothing was interposed between the rope and the cast-iron driving-pulley, and in addition the rope was injudiciously treated with pure oil. Since then, the tread of the driving pulley had been bedded with hemp; and Archangel tar mixed with American natural oil had been used as the lubricant for the rope with satisfactory results.

Mr. J. T. Stobbs (Stoke-upon-Trent) wrote that the tail rope had now been in continuous use at Sneyd Colliery for nearly 19 years, and during that period no accident had ever been caused by the appliance. He agreed with Mr. A. L. Steavenson that

scroll-drums were not suitable unless there was some distance between the drum and the headgear-pulleys; and in such circumstances they were a source of trouble and danger, as was proved by their frequent trial and abandonment. Prof. H. Louis stated that "the weakest part, the cap, had to bear the maximum strain," but careful consideration would shew that the capping only had to bear the maximum load (namely, the weight of the cage, chains, tubs, mineral, and length of balance rope equal to the depth of the shaft) when the cage was at or near the surface, and its velocity was approaching zero. On the other hand, when any part of the winding rope was in the same position, it supported the same load when the velocity of the cage was much greater. It will thus be recognized that the weight on the capping of the rope never exceeds that on any portion of the winding rope between the cage and the pulleys.

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The following paper by Mr. William Tattley on "Sinking through Swamp, Clay and Sand" was read as follows:—

# SINKING THROUGH SWAMP, CLAY AND SAND.

By WILLIAM TATTLEY.

The Waikato coal-field, Auckland, New Zealand, has only one workable seam, varying in the Huntly district from 21 feet to 60 feet in thickness (classed as brown coal). Almost the whole of the measures in this district are overlain by sand and clay, and in places by swamp containing large logs of timber. The sand in some parts of the field lies immediately on the seam, making shaft-sinking difficult and costly for the depths sunk, where such conditions exist.

When the writer took the management of the Taupiri Extended colliery in 1889, the present winding-shaft, after much difficulty and great cost, had just been sunk through the coal. The cylinder, 10 feet in inside diameter, is 80 feet in length and is 8 inches out of plumb, and is cracked from the bottom upwards for a distance of 16 feet, in consequence of the pressure. Large rings made of 56 pounds railway rails were put inside the cylinder to strengthen it. As these rings reduced the size of the shaft considerably, making it impossible to work two cages, they were removed, and a greater number of rings, 6 inches wide and 2 inches thick, were inserted. Moreover, cast-iron bearers or buntons were fixed, 4 feet apart, in the cylinder, on account of the slight angle caused by the cylinder being out of plumb, and 7 feet apart below the cylinder. The cast-iron bearers were placed in the centre of the shaft, so as to reduce the space occupied by them to a minimum: the entire space between the cages is only 7¾ inches, comprizing the conductors, 3 inches thick each, and the bearers, 1¾ inches thick. By this means, the writer was able to insert two cages carrying tubs containing 10 cwts. of coal, as well as leaving room for the pumps and air-pipes.

As the New Zealand Coal-mining Act compelled the owners of the mine to sink a second shaft within 18 months from the commencement of working the mine, or to reduce the number of persons employed to 10, immediate preparations were therefore made for sinking the second shaft; and it was decided to sink the

cylinder by hydraulic pressure, and to use a dredge for removing the material from the inside of the cylinder.

A suitable site, about 660 feet from the winding-shaft was selected, and a bore-hole put down, to ascertain the nature of the ground, as well as the depth to the floor of the seam. This information being obtained, a series of bore-holes were put down round the periphery of a circle, 12 feet in diameter, 1 foot apart, to a depth of 35 feet, to ascertain whether there were any logs likely to obstruct the sinking of the cylinder. These bore-holes shewed that a large log was under the selected site. Another site was chosen, about 130 feet from the first, and the complete circle of bore-holes was put down without encountering any obstruction (Fig. 1, Plate I.).

Preparations were then made for sinking the cylinder, 10 feet in inside diameter, in 2 feet sections and six segments in a ring. The horizontal and vertical joints of the segments are slightly raised above the flanges for 1 inch in width and faced for the purpose of making the cylinder water-tight, and strips of white flannel soaked in red-lead and oil were placed between the joints (Figs. 5 and 6, Plate I.). The steel leader or cutter was 16 inches long, and at the cutting-point it was 1½ inches larger in diameter than the cylinder, and built of six segments.

A frame, 6 feet high, was erected to keep the cylinder vertical, whilst sinking. Two kauri timber beams, 30 feet long, by 36 inches by 24 inches, were fixed 6 feet apart, and parallel to each other, 10 feet above the surface; and at right angles to these and on the top of them, two other beams, 30 feet long by 24 inches by 24 inches were similarly placed, and the outside-edge of the four beams was placed directly over the outside of the cylinder. The beams were intended to apply pressure to the cylinder (Figs. 2, 3 and 4, Plate I.). Twenty rough round piles, 15 inches in diameter and 20 feet long, were driven into the ground, leaving 10 feet of their length above the surface for the purpose of carrying the beams: the piles answering the twofold object of carrying the beams, and preventing them from rising when pressure was applied to the cylinder. The piles were placed as far from the cylinder as possible, to prevent them from being disturbed by any running of sand, and this accounts for the length of the beams. When all the piles were driven home, the tops were cut level and tenoned, and the beams mortised to receive the tenons. There were three piles at each end

of the lower pair of beams, and two piles at each end of the upper pair of beams, and two wrought-iron straps, 4½ inches wide by ¾ inch thick at each end of the lower beams and one at each end of the upper beams. The straps went over the top of the beams and 4½ feet down the sides of the piles, to which they were fastened by three bolts, 1¼ inches in diameter, passed through each strap and the piles. In addition to this, iron rods were hung from the upper beams to carry a platform, upon which were stacked the bricks intended for use in walling the shaft below the cylinder; and the weight of the bricks assisted in preventing the beams from lifting.

The beams being fixed in position, the head-gear and platform, which were also carried on piles, were erected and the machinery for dredging and winding put into position, the winding-engine about 45 feet from the dredging-engine, and on the same side of the shaft (Fig. 4, Plate I. and Fig. 9).

All the preliminary arrangements being completed, sinking operations commenced. The leader or cutter was fixed in position, and the first section of the cylinder built on it in segments and bolted to it; the second section was then built on the first, and so on; care being taken to insert the flannel packing between the vertical and horizontal joints. After building up the cylinder, so as to allow of the hydraulic jacks being inserted between it and the beams, pressure was applied to the cylinder to force it downward: steel plates ½ inch thick, being placed between the head of the jacks and the beams to prevent the jacks from crushing into the timber; and wooden blocks were packed between the cylinder and the jacks as required. After forcing the cylinder down to a sufficient depth, the jacks were removed, and one or more sections built on to the cylinder. The jacks were then fixed in position again, and arranged so as to bring pressure to bear on any part of the cylinder most required (Fig. 3, Plate I.). This process continued until the cylinder was forced down to the required depth.

Whilst the cylinder was being sunk, a Priestman dredge was used inside it, the cutter being kept well ahead of the dredging; and this contrivance, together with the water in the cylinder, which rose to the surface, prevented the sand from running into the cylinder.

As the dredge brought the débris to the surface, a lurry carrying a truck passed under it, and the débris were dropped into the

truck: the lurry was then pushed back from over the shaft, and the truck run to the rubbish-heap and emptied.

At a depth of 16 feet from the surface, the dredge commenced to bring up rotten timber and continued to do so, more or less, to a depth of 25 feet, when a bed of stiff clay was found, which offered considerable resistance to the sinking of the cylinder. It was thought that possibly a boulder or log of timber was the cause of the obstruction, and as it was feared that the cylinder might be forced out of plumb, if too much pressure was used, the water was wound out of the cylinder and workmen were sent down to clear out the débris to the cutter. When the point of the cutter was reached, fire-damp issued with considerable force into the cylinder. Work was stopped for 24 hours to allow the gas to escape, during which time the water inside the cylinder was a seething mass of bubbles, and when it abated work was resumed. At 30 feet below the surface, the cylinder passed through stiff clay, after which it sank freely under the pressure of three jacks, of 100 tons, 50 tons and 40 tons power respectively.

At a depth of 40 feet, fine pumice-sand was found and the surface, around the cylinder, commenced to sink. Extra pressure was then applied to the cylinder, stiff clay was filled into the cavities and well rammed, and the cutter was kept well ahead of the dredging.

Down to a depth of 90 feet, sand and gravel were passed through, and at that depth fire-clay was struck. At 91½ feet, the fire-clay became too hard to allow of the cylinder being forced down, the water was again wound out of the shaft, and workmen sent down to clear around the cutter, taking out only sufficient ground to allow of the sinking of the cylinder, which was forced down as the cutter was cleared.

At 93 feet, soft sandy fire-clay was cut, the cylinder was forced down to this, the hard fire-clay was removed from the centre, and the water allowed to rise; after which, dredging was resumed, and the pressure of five jacks, three of 100 tons, 50 tons and 40 tons were required to force the cylinder.

At 98 feet from the surface, strong fire-clay was met with, and as the cylinder could not be forced down any further, the water was wound out of the shaft, a bore-hole was put down at the bottom to ascertain the nature of the strata, and a seam of coal, 6 feet thick, was cut at a depth of 3 feet. The use of the dredge was

discarded, and ordinary sinking commenced, the cylinder being forced downward as the work advanced.

At 106 feet from the surface, a suitable bed was obtained in the coal for the cast-iron wedging-ring, 16 inches wide and 6 inches in height (Figs. 7 and 8, Plate I.), hollow, with strengthening ribs, open on the inside of the shaft and closed on the outside. The ring was wedged, made water-tight, and fixed in such a position that a 2 feet ring of the cylinder built upon it would close the space between the ring and the cylinder, after taking off the cutter.

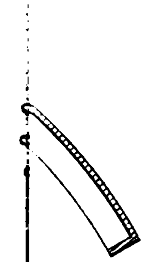
Anticipating a possible forcing of the fire-clay from behind the cylinder and a running of the sand, when taking off the cutter, wooden wedges of various sizes and shapes were sent down the shaft before commencing to remove it from the cylinder. These preparations having been made, the first segment was removed. As anticipated, the pressure forced very stiff fire-clay down the outside of the cylinder; wedges were driven vertically behind the cylinder, and the running stopped. A second segment was removed, and the same process of wedging was repeated. As there was now room for the insertion of a segment of the closing section of the cylinder, it was built on the wedging-ring and bolted to the cylinder. A third segment of the cutter was then removed, a second segment of the closing section of the cylinder built on the wedging-ring, and bolted to the first and to the cylinder. This process was continued until all the segments of the cutter were removed, and the closing section of the cylinder inserted. At no time were more than two segments of the cutter taken off before inserting another segment of the cylinder. After inserting the closing section, wedges were driven between the wedging-ring and the cylinder.

The cylinder is 106 feet in length, and only 2 inches out of plumb at the bottom.

On completing the cylinder-portion of the shaft, the heavy beams and timber were cleared away on the surface, and sinking in the ordinary way began.

The sinking of the cylinder was commenced on July 30th, 1891, and was completed on October 19th of the same year; but as there were stoppages, caused by waiting for a portion of the cylinder, amounting to 25 days, the actual time occupied in sinking and completing the cylinder portion of the shaft was only 8

Fig. 9. View of the Taupiri Extended Colliery.



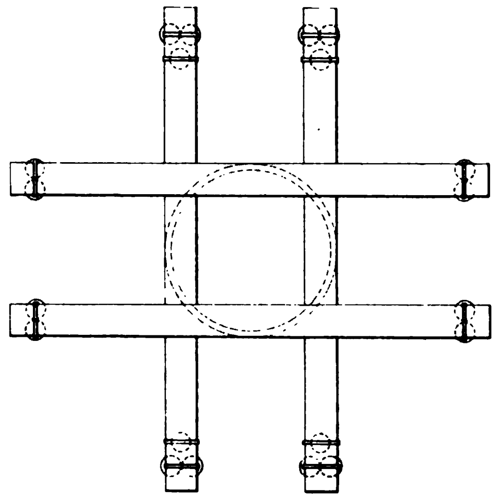


Fig. 2.

Scale, 12 Feet to 1 Inch.

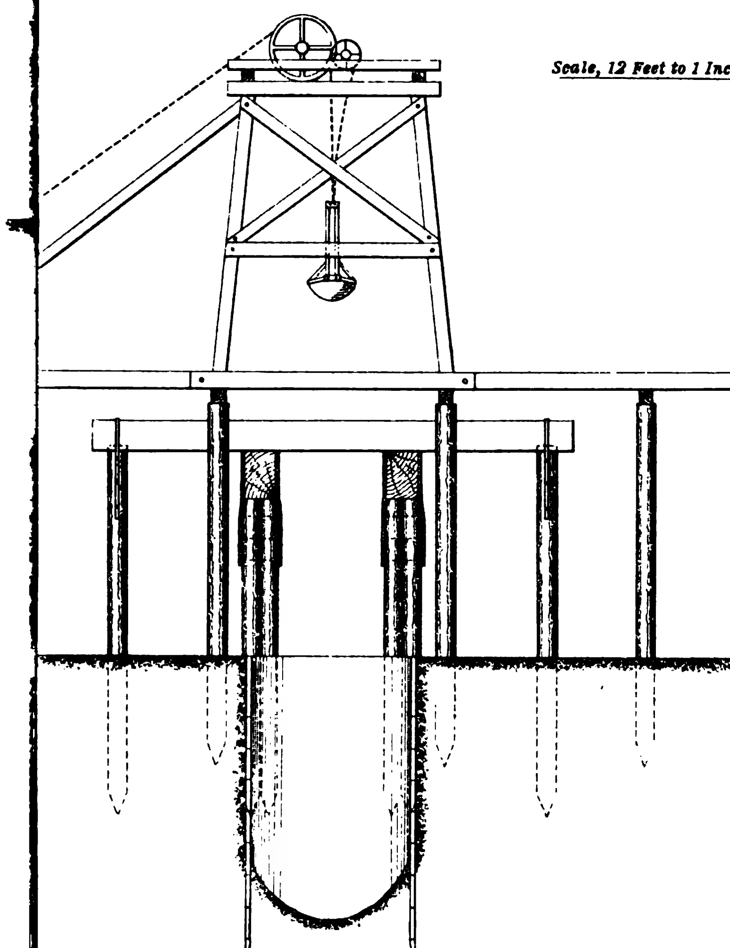


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Fig. 4.

Fig. 9. View of the Taupiri Extended Colliery.

"... Swamp, Clay and Sand."



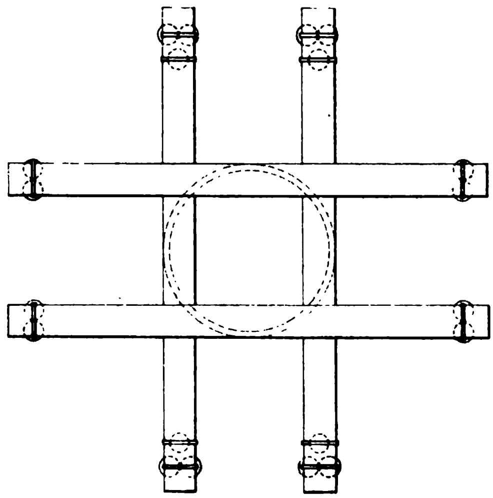

Fig. 2.

Scale, 12 Feet to 1 Inch.

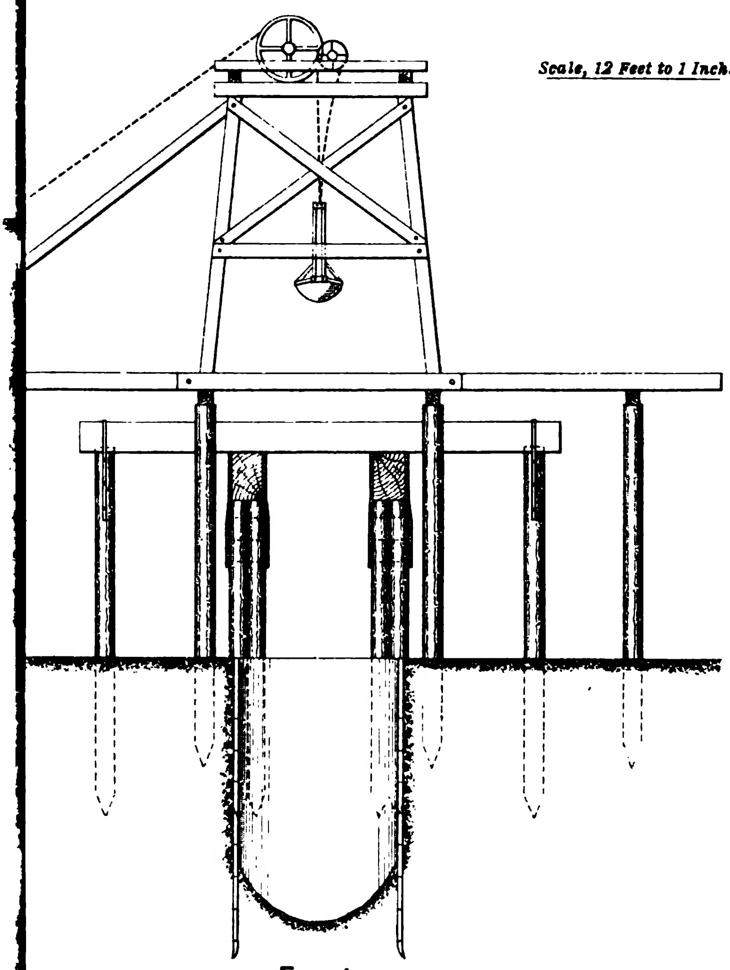

Fig. 4.

weeks; and 15 weeks from the commencement of the sinking to the completion of the shaft.

The total depth of the shaft is 204 feet, and the seam at this point is 21 feet thick.

Two tenders were received for labour only, the owners to find all plant and materials, one of £2,110; and one of £1,724 for the cylinder portion of the shaft, and of £43 per fathom below the cylinder, which would amount to £2,416. The actual cost for labour was as follows:—

| | £ |
|---|---|
| Surface arrangements, driving piles, fixing machinery, etc. ... | 237 |
| Sinking and completing the cylinder ... ... ... ... | 433 |
| Sinking the shaft below the cylinder ... ... ... ... | 495 |
| Total ... | £1,165 |

The rate of wages paid was 8s. per day of 8 hours to enginemen and sinkers, 9s. to chargemen, and 7s. for surface-workmen.

The section of strata sunk through was as follows:—

| No. | Description of Strata. | Thickness of Strata. Feet. | Depth from Surface. Feet. |
|---|---|---|---|
| 1. | Pumice sand ... ... ... ... ... ... | 16 | 16 |
| 2. | Sand and soft clay, with timber ... ... ... | 9 | 25 |
| 3. | Stiff yellow clay ... ... ... ... ... | 5 | 30 |
| 4. | Soft sandy clay ... ... ... ... ... | 10 | 40 |
| 5. | Pumice sand ... ... ... ... ... ... | 45 | 85 |
| 6. | Coarse gravel ... ... ... ... ... ... | 5 | 90 |
| 7. | Fire-clay ... ... ... ... ... ... | 3 | 93 |
| 8. | Soft sandy fire-clay ... ... ... ... ... | 5 | 98 |
| 9. | Strong fire-clay ... ... ... ... ... | 3 | 101 |
| 10. | COAL ... ... ... ... ... ... ... | 6 | 107 |
| 11. | Fire-clay ... ... ... ... ... ... | 76 | 183 |
| 12. | COAL ... ... ... ... ... ... ... | 21 | 204 |

The PRESIDENT (Mr. J. G. Weeks) said that Mr. Tattley had successfully conducted a very difficult sinking and he was to be congratulated on having found a seam of coal, 21 feet thick. He proposed a vote of thanks to Mr. Tattley for his paper.

The resolution was cordially adopted.

Mr. H. D. HOSKOLD'S "Remarks upon Prof. H. Stroud's Paper on 'Magnetic Declination and its Variations'" were read as follows:—

# REMARKS UPON PROF. H. STROUD'S PAPER ON "MAGNETIC DECLINATION AND ITS VARIATIONS."*

By H. D. HOSKOLD.

The writer has carefully studied the excellent paper by Prof. H. Stroud, on "Magnetic Declination and its Variations" and what Mr. Beanlands has stated in reference to the coarse magnetic-needle readings of the miner's dial is true in a general sense. The writer is also in accord with the statements made by Mr. Beanlands on February 9th and April 27th, 1895.† An examination of the colliery-plans of some of the North-of-England mines, and other places, renders it difficult to understand clearly what length of base-line Mr. J. A. Ramsay (Littletown) meant when he stated that "the length of which could not by any possible means exceed a very small fraction more than the diameter of the pit-shaft."‡

Referring to the very valuable standard work on *Mining Engineering*, by Mr. G. C. Greenwell (whose vast professional practice extended over more than half a century) we find that, he stated that "the system almost exclusively adopted in the Newcastle coal-field, and also, with certain modifications made use of pretty generally in Scotland, Lancashire and elsewhere, is that termed the bord-and-pillar, or post-and-stall method of working coal,"§ he further stated "suffice it to say that the drift intended for the main outlet or rolleyway from the colliery-workings to the shaft should be driven with about $\frac{5}{16}$ inch rise per yard, each way from the shaft, and as straight as possible, in order that it may be adapted to the application of machinery as the tractive power to be used upon it."‖ The plans of colliery-workings, illustrated in Mr. Greenwell's book, show that the main drift is a straight line for a considerable distance from the shafts, so that nothing would be easier in such cases than to prolong or continue a survey-

* *Trans. Inst. M.E.*, 1894, vol. vii., page 268.

† *Ibid.*, vol. ix., pages 26, 28, 221 and 222.

‡ *Ibid.*, vol. ix., page 26.

§ 1869, page 196, and Plates 56 to 60.

‖ *Ibid.*, pages 196 and 197.

line across the diameter of the shaft, and as far as may be necessary along the straight portion of the drift intended for "the main outlet or rolleyway from the colliery-workings," so as to carry out Mr. Beanlands' system of connecting the underground workings with the surface, as also for the general construction of the colliery-plan. It is not, therefore, surprising that he (Mr. Beanlands) found so little difficulty in his surveying operations.

Mr. G. C. Greenwell lectured upon mining-engineering in 1852, his book appeared some years after, and it is very pleasing to find, as he says in his preface, that many works have been laid out and executed in accordance with his recommendations. During the long interval which had elapsed, a large number of collieries must have been opened in different parts of Great Britain, with drift-roads from the shafts "as straight as possible," and also as long as possible, and one would not, therefore, expect to find, to-day, such short and tortuous drifts leading from the shafts as was the case one hundred years ago.

Mr. J. A. Ramsay further said that, "in taking a transit-line down a shaft up to 14 feet in diameter, the base-line was too short."* The writer understands the sense of Mr. Beanlands' paper to mean that two marks were set in the bottom of a shaft, as far apart as its diameter would allow, and that the transit-instrument must be adjusted in such a manner over the top of the shaft that finally the vertical hair in the focus of the telescope would bisect the two marks, that is, it would be in the same vertical plane, and that when the telescope is raised horizontally, the same underground line is reproduced at the surface, also in the same vertical plane, and permanently marked, for reference with any other line.† Mr. Beanlands says "by this means the underground survey can be commenced and carried forward to any extent by means of the theodolite."‡ This could not, however, be effected from Mr Ramsay's base-line of 14 feet, "which could not by any possible means exceed a very small fraction more than the diameter of the pit-shaft."§

It appears to the writer that no mistake or misunderstanding could have occurred, if it had been stated that first of all a proper distance must be selected along the drift leading from

* *Trans. Inst. M.E.*, vol. ix., page 29.

† *Trans. N.E. Inst.*, 1856, vol. iv., pages 267 to 270.

‡ *Ibid.*, vol. iv., page 267. § *Trans. Inst. M.E.*, vol. ix., page 26.

the shaft to the first turn or angle in it, and then a line drawn from this point to and across the bottom of the shaft would be a portion of the line represented by Mr. Beanlands' two marks to be seen from the surface, so that whether the diameter of the shaft is 14 or 10 feet, is not the whole of the question, and unless in some very peculiar cases, which Mr. Ramsay must have had in his mind, it is impossible to see how his arguments can apply adversely to Mr. Beanlands' system.

The great facility and accuracy with which an underground survey may now be conducted by the use of a superior and specially constructed class of surveying-instruments, as compared to former times, are advantages of no small importance and value.

When, however, there are no expensive tunnels or drifts through solid rock of great length to be constructed, operating from one or more points at the same time, or to be made to intersect a fixed point; pits to be sunk from a selected point at the surface to strike another given point below ground—from which probably workings may be commenced upwards to meet the downward sinking, such as have been practised in the United States; distant boundary-lines to be defined with absolute precision; old dams of water in old mines to be searched for and guarded against; and accurate plans, sections and models to be made; then, for the object of saving time, expense and labour, nothing better than the magnetic compass or miner's dial could be employed, and the particular form that such an instrument should have, must be a question for the determination of persons intending to use it.

The writer is, however, fully aware that the magnetic needle has rendered great service in advancing mining in past times, and considering the affection—if the term is allowable—which many persons possess for that instrument, it may not be prudent or convenient to abandon entirely so good an old servant and friend. No doubt the miner's dial will always retain its own particular use and value, for a certain class of work in which the greatest possible accuracy is not sought.

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Mr. James Henderson (Truro), having read with much interest Mr. H. D. Hoskold's remarks, was desirous of making a few comments on magnetic readings, and the application of the so-called miner's dial to underground and surface-surveying. In roomy and extensive underground workings, especially in coal-pits, where

large perpendicular shafts are commonly used, the theodolite is to be preferred to the ordinary dial in conducting a traverse, particularly when it is required to connect the workings with objects on the surface, such, for instance, as a distant shaft to which it is proposed to drive a level or heading in order to communicate for ventilation or other purposes; but in metalliferous mines, where perpendicular shafts are the exception and not the rule, the miner's dial is still pre-eminent among surveying instruments, and the great number of strictly accurate traverses made by its means bear witness to its merits.

Mr. H. D. Hoskold refers to "coarse magnetic-needle readings," but there is no reason for this appellation. A good needle, scientifically made, and pivoted on a ruby, with a vernier attached to the north end, enabling the operator to read a bearing to at least, 2 or 3 minutes, can be procured, which would admit of work of great accuracy being effected through its use; and it is the fault of the surveyor if he uses one of a coarser or commoner description. A miner's dial should be treated with as much care as a watch, and under such conditions, the surveyor who has one of the description suggested, need have no fear of incorrect resultant bearings.

When surveying with the miner's dial where magnetic attraction is found to exist, such as when traversing over a line of rails, or even when it is only suspected, back readings, as well as forward ones, should be taken, and the true bearing of each draft worked out by calculation.

Thus, for example the dial is supposed to have been set up at *A*, in a level or heading and a back observation taken to *Z*, a station or starting-point in, say, the centre of the shaft, giving a bearing of 265 degrees 42 minutes; a forward sight to *B* would then be taken, reading 274 degrees 06 minutes. After measuring each of the lines, the dial would be removed from the stand at *A*, and placed on the stand at *B*, and a back sight taken to *A*, the bearing reading, not 274 degrees 06 minutes (which it would, had there been no local attraction caused by a tramway along which the traverse is supposed to be made) but, say 278 degrees 00 minutes; then a forward sight to the stand with candle or lamp on its top at *C*, giving a compass-reading of 256 degrees 40 minutes. Then, again, the dial would be shifted to *C*, whence the bearing was 264 degrees 33 minutes on looking back to *B*; the stand at *A* having, in the meantime, been set up in a new position at *D*. The

fore-bearing to $D$ was 272 degrees 00 minutes. Now at $D$, it is supposed there are no rails, these having been taken up and removed to some distance, say not less than 30 feet, to afford an opportunity of obtaining an accurate bearing. When the dial was removed from its stand at $C$ and placed on a stand at $D$, the back observation which was taken to $C$ gave the true bearing of 269 degrees 30 minutes and the forward one to $E$, also of course true, of 274 degrees 15 minutes, and so on for any required distance.

TABLE I.—SURVEY OF THE FRAME MINE; DATE, JUNE 12, 1900, BY JAMES HENDERSON, WITH DIAL No. 7; PLAN No. 3,423. FROM STATION IN CENTRE OF ENGINE-SHAFT, AT THE 130 FATHOMS LEVEL.

| Station. | Back-Bearing. | Fore-Bearing. | Angle. | True Bearing. | Distance. | Offsets. Right. | Offsets. Left. | Inclination: Rising or Falling. | Hypotenuse. | Perpendicular. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dgs. Min. | Dgs. Min. | Dgs. Min. | Dgs. Min. | Feet. | Feet. | Feet. | Dgs. Min. | Feet. | Feet. |
| A | 265 42 | 274 06 | — | 274 59 | 69·54 | 6·5 | 1·4 | — | — | — |
| B | 278 00 | 256 40 | — | 283 23 | 47·08 | 2·5 | 5·7 | — | — | — |
| C | 264 33 | 272 00 | — | 262 03 | 121·40 | 3·0 | 3·5 | — | — | — |
| *D | 269 30 | 274 15 | — | 269 30 | 99·80 | 4·2 | 3·0 | — | — | — |
| E | — | — | — | 274 15 | 209·08 | 4·5 | 2·8 | — | — | — |
| | 1,077 45 | 1,077 01 | | | | | | | | |

* No attraction at station $D$.

The difference between the sums of the back-bearings and of the fore-bearings is 44 minutes. The true bearing of the first line, $ZA$, is 274 degrees 59 minutes; and the true bearing of the last line, $DE$, is 274 degrees 15 minutes.

In a long traverse, it is advisable to check the accuracy of the readings recorded, by repeated true bearings. The use of three tripod-stands, and two candlesticks or lampholders is strongly recommended, if not almost indispensable. The term back-sight implies an observation taken with the operator's eye at the forward or leading end of the pair of sights.

Table I. is the copy of a leaf from the dialling-book used in the foregoing supposed traverse, with the calculated true bearings worked out. The figures in Table I. represent the result of a traverse of a heading of so level a character as not to affect the horizontal measurements.

The diallings shown in Table II., however, are supposed to have been taken in a diagonal or underlying shaft for a part of the distance where the movement of the pump-rods compel the observer to throw off the needle and record the angles on the

theodolite principle. It will be noted that a true bearing can be taken at any station, and not necessarily at the beginning or end of the traverse, as exemplified in Table II. (Fig. 1).

TABLE II.—SURVEY OF THE FRAME MINE; DATE, JUNE 12TH, 1900, BY JAMES HENDERSON, WITH DIAL NO. 7; PLAN NO. 3,424. FROM STATION IN CENTRE OF ENGINE-SHAFT, AT THE 130 FATHOMS LEVEL. SHAFT, 13 FEET 6 INCHES, UNDERLYING SOUTH.

| Station. | Back-Bearing | Fore-Bearing | Angle. | True Bearing | Distance. | Offsets. Right. | Offsets. Left. | Inclination Rising or Falling. | Hypotenuse. | Perpendicular. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dgs Min | Dgs Min | Dgs Min | Dgs Min | Feet. | Feet. | Feet. | Dgs. Min. | Feet. | Feet. | |
| A | — | — | 6 20 | 157 24 | 26·10* | — | — | F 67 00 | 66·80 | 61·05 | At 140 fathoms level, 2 feet east of centre. |
| B | — | — | 359 50 | 163 44 | 31·80* | — | — | F 64 05 | 72·75 | 65·44 | At 150 fathoms level, 1 foot east of centre. |
| C | — | — | 2 00 | 163 34 | 27·05* | — | — | F 63 50 | 61·33 | 55·05 | At 160 fathoms level, at centre. |
| D | 184 00 | 97 42 | — | 165 34 | 73·42 | 3 | 4 | — | — | — | In cross-cut south, at east level. |
| E | 90 49 | 103 30 | — | 79 16 | 32·20 | 6 | 3 | — | — | — | In 160 fathoms east. |
| F | 101 40 | 124 06 | — | 91 57 | 48·72 | 1·5 | 5 | — | — | — | ,, ,, ,, |
| G | 116 29 | 108 21 | — | 114 23 | 61·10 | 3 | 3 | — | — | — | ,, ,, ,, |
| H | 106 15 | 112 42 | — | 106 15 | 54·22 | 6 | 2 | — | — | — | Rails removed. |
| J | 110 48 | 109 50 | — | 112 42 | 26·75 | 4·5 | 3·5 | — | — | — | do. |
| K | — | — | — | 111 44 | 18·42 | 3·5 | 3·5 | — | — | — | do. |
| | 710 01 | 656 11 | | | | | | | | | |

* Calculated.

The difference between the sums of the back-bearings and of the fore-bearings is 53 degrees 50 minutes. The bearing of the line *CD* is 165 degrees 34 minutes; and the true bearing of the line *JK* is 111 degrees 44 minutes.

The correctness of the working out of the true bearings in Table II. is proved by adding up the back and fore-bearings. If the sum of the back-bearings be greater than the sum of the fore-bearings, deduct their difference from the bearing of the first draft, and the result will be the bearing of the last one. Thus, the total of the back-bearings in Table II. is 710 degrees 01 minutes; and that of the fore-bearings is 656 degrees 11 minutes. Now, if the difference, 53 degrees 50 minutes, be deducted from the bearing of the line *CD*, 165 degrees 34 minutes, it gives the true bearing of the line *JK*, 111 degrees 44 minutes. If the total of the fore-bearing exceeds that of the back-bearings, the difference must be

added to the first bearing, and the true bearing for the last line will be given. A similar check is shown in Table I.

It is too often customary, when surveying with the miner's dial, to throw off the needle when local attraction occurs, and to continue the traverse with the parallel plates of the instrument, as with the theodolite, but the writer does not altogether recommend the proceeding, for the simple reason that the ordinary dial is too often mounted on a defective tripod, which from age or bad usage has become crippled or, at all events, shaky, and liable to the effects of torsion caused by loose joints. Hence, if the slightest lateral movement takes place in the tripod-head on which the dial revolves, it is obvious that a correct angle cannot

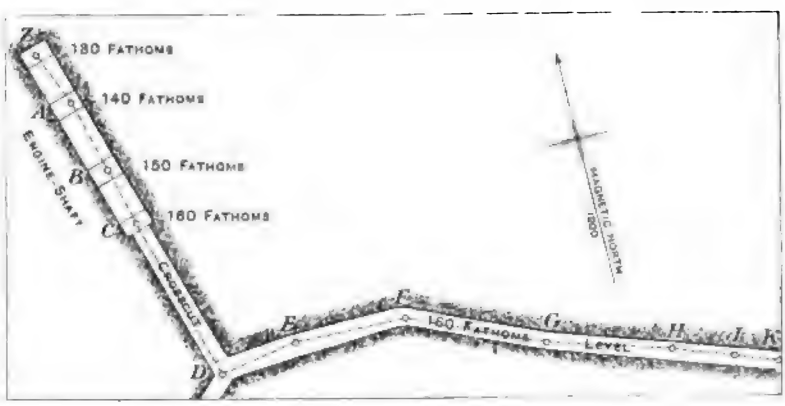


FIG. 1.—PLAN. SCALE, 83⅓ FEET TO INCH.

be obtained, and, in his (Mr. Henderson's) opinion, serious errors have occurred in consequence. Whereas, however imperfect the tripod-heads may be when back and fore compass-bearings are taken, the latter are not affected. In point of fact, the observer is working with a magnetic base for each draft, instead of depending on the rigidity of the stands, and so long as the needle of the dial is in perfect order, so will his traverse turn out as regards accuracy.

It is important that either the same compass should be used in an underground survey as at the surface in connection with it, or their differences if any, should be ascertained; and it is, also, a matter of importance that both surveys, underground and surface, should be made as nearly as possible at the same period,

to avoid differences which might arise from variations of the needle in the interval.

The annual variation of the needle can be readily ascertained by the following simple means. The surveyor has merely to place his dial at precisely the same spot every year or at any intermediate time, turn his sight to some distant wellknown object, take the bearing, and compare it with that of preceding years, when the variation will be at once ascertained. It would tend to facilitate mine-surveying operations considerably, if, in the vicinity of mines, stones or other permanent marks were set up in the precise direction of the true meridian. By fixing the dial at one of these marks and looking to the other, not only could the annual variation be ascertained, as before described, but the actual declination of the compass from the true north-line could be registered with the greatest ease.

The diurnal or daily variation of the needle is of less consequence, being very slight, but even this could be overcome by taking the bearing both at the surface and underground at the same preconcerted hour of the day, if it were necessary to connect, for any purpose, objects on the surface with underground works, and thereby to ascertain their relative positions.

There is no necessity for disfiguring a working-plan of a mine, by covering it over with magnetic meridian lines to plot from year after year. The operator should discover, in the way indicated, the variation of the compass-needle from the first line, magnetic or true meridian as the case might be, and make the requisite alteration in each of the bearings of his drafts, and, then, plot them in the usual way with a protractor, or preferably, calculate the whole by co-ordinates. This it is unnecessary to state, is the most accurate, indeed the only strictly accurate, method of recording the result of a survey.

There are several instruments of modern invention which have been recently adopted by mine-surveyors to take the place of the miner's dial, several of them of great merit. Admirable work has been done through their use, yet, after all, so far as metalliferous mines generally are concerned, the miner's compass must be resorted to, in order to give the polarity of the whole of the survey where such instruments are used, whether at the surface or underground; and, consequently, the dial is the instrument which ought to have the credit for the results thus obtained.

In a recently published work on mine-surveying, its author, in describing the use of the miner's dial, while speaking in no disparaging terms of the instrument, indeed, on the contrary, rather commending its use than otherwise, but for ordinary purposes only, says "of course everything of the nature of tools, rails, and sleepers leaning against the side of the drivage, trams, etc., should be removed to a safe distance; but as regards the road such removal is not in the least necessary." Such a statement must astonish any surveyor who has had much practice with a dial, and wishes to do or has done precise work through its means. The bearings, taken under such conditions would be utterly valueless, except to show that attraction existed. The effects of this attraction must be overcome by back and fore observations in the manner previously described. No wonder that fault is found with the miner's dial, when the real culprit is the man who so misuses it.

He (Mr. Henderson) repeated his assertion that the miner's dial, if properly constructed, and used with care, could not, in cases where no direct communication can be established with the surface permitting of the use of a theodolite, be surpassed for accuracy and reliability, and the very many instances in which he had most successfully applied this instrument in very intricate traverses of great variety induced him to stand forth boldly as one of its champions.

Mr. H. D. Hoskold wrote that it was pleasing to find Mr. Henderson concordant and justifying his principles by his practice and, at the same time, admitting that the theodolite was superior to the miner's dial for some kind of work. He (Mr. Hoskold) could not see any reason to induce him to extend his views more than he had done on various occasions and places, upon the sole use of the magnetic-needle.

Prof. H. Stroud (Durham College of Science) wrote that Mr. Hoskold had contributed a useful summary of the points referred to in the various papers and discussions on mine surveying. The laying down on a colliery-plan of the true meridian seems obviously desirable. In America, it is the universal custom. Even when this is done, the compass-needle will no doubt prove of considerable service under many circumstances; but the user

must, of course, clearly understand the variations to which the magnetic declination is subject.

The President moved that a vote of thanks be accorded to Mr. Hoskold for his interesting paper.

Prof. H. Louis seconded the motion, which was cordially approved.

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Mr. H. D. Hoskold's "Remarks upon Mr. A. L. Steavenson's paper on 'The Mode of obtaining a True North Line'" were read as follows:—

## REMARKS UPON MR. A. L. STEAVENSON'S PAPER ON "THE MODE OF OBTAINING A TRUE NORTH LINE."*

By H. D. HOSKOLD.

Referring to Mr. Steavenson's very ingenious and useful paper "The Mode of Obtaining the True North Line,"*—as Mr. Beanlands stated—there are several modes of setting out such a line, that by the altitude of the sun or other celestial body, calculating the azimuth being the most common; but the writer prefers the mode by equal altitudes of a planet, more especially of a star, observed on each side of the meridian, half the intervening horizontal arc indicating a point in the astronomical meridian. Apart from the apparent inconvenience of having to wait a little, in order to obtain the second contact of the star with the centre of the cross-hairs in the focus of the telescope of a transit-theodolite, this is a very superior method, possessing the advantages of being independent and free from effects of latitude-declination of the sun and such elements as usually enter into the calculation when the azimuth-problem is adopted. A similar result would be obtained by observations of the sun, east and west of the meridian; but, in this case, an allowance would have to be made for change of declination during the interval, involving also the latitude of the place in the calculation. All such problems as refer to time, azimuth, and meridian-determinations are exhibited in Simms' *Mathematical Instruments*, 1836; Butler Williams' *Practical Geodesy*, 1843; Smith's and Thuillier's *Indian Surveying*, 1851; Rankine's *Civil Engineering*, 1862; Hoskold's *Mine Surveying*, etc., 1863; and Frome's *Trigonometrical Surveying*, 1873; earlier and more modern works upon astronomy, geodesy, etc. It is, therefore, difficult to understand what Mr. Steavenson meant when he stated† "that during all these 40 years . . no one has at any time supplied the much-felt want of the means for obtaining

* *Trans. Inst. M.E.*, 1895, vol. x., pages 53 to 61.

† *Ibid.*, vol, x., page 54.

the true north line." Probably, however, he meant to convey the idea that nothing upon the subject could be found written by any of the members in the *Transactions* "during all these 40 years."

During the last 16 years, the writer, in his official capacity, has had extensive experience with so-called good watch and chronometer timekeepers, by the most renowned makers; and when engaged upon explorations for mining, geological, geodetical and other scientific matters in the high altitudes of the Argentine Republic, the erratic behaviour of such instruments was very curious as well as perplexing. It was found that change of altitude produced acceleration, and variable rates, while sudden oscillation or jerks had the contrary effect. Considering this, as also the precise attention required in reading off fractions of time to corresponding altitudes, and the great facility with which small errors creep into the work, the writer is inclined to agree with the sense of Mr. Beanlands' remarks concerning Mr. Steavenson's mode of determining the astronomical meridian. If the gun at South Shields, to which Mr. Steavenson refers, was fired for the purpose of giving the time, namely, noon (and probably to be wired to other places) some 9·5 hours must have elapsed before Mr. Steavenson took his observation of the star; but he does not mention anything about the rate of the watch which he used during that interval, or its effects upon the time as affecting the position of the meridian-line.

The mode of setting out the true meridian-line, exhibited in Mr. Steavenson's paper, is no doubt sufficient for most ordinary purposes; but it would have been more accurate if the timekeeper employed had been rated, and the latitude and longitude of the given place determined by actual observation and calculation, and not obtained from a map which, for many reasons, could not afford such elements with such absolute precision.

Students in the profession desirous of setting out the meridian by the mode advocated by Mr. Steavenson, and wishing to observe afterwards the transit of the same star on various successive nights, for time or meridian purposes, should remember that the mean solar day is longer than the sidereal day by 3 minutes 55·91 seconds of mean solar time, consequently the same star would return to the meridian or other given altitude at the same place 3 minutes 55·91 seconds earlier each day than it did on

the preceding one. This acceleration of the star offers, therefore, all that is required, in order to determine the astronomical meridian with the use of a transit-theodolite, and well regulated chronometer, or half-chronometer watch, as also to determine the rate or gain of the timekeeper at the same time. The plan to be adopted is that of equal altitudes of the same star on each side of the meridian.

| | Hrs. | Mins. | Secs. |
|---|---|---|---|
| Suppose an altitude is taken of the star to the east of the meridian at ... ... ... ... ... ... ... | 7 | 10 | 35 |
| And an equal altitude is taken of the star to the west of the meridian at ... ... ... ... ... ... ... | +11 | 9 | 30 |
| The sum of the times of observations is ... ... ... ... | 18 | 20 | 5 |
| The half-sum of the times, and the time of meridian passage of the star is ... ... ... ... ... ... ... | 9 | 10 | 2·50 |
| The acceleration of the star in 24 hours is ... ... ... | −0 | 3 | 55·91 |
| The time of the star passing the meridian on the following night is ... ... ... ... ... ... ... ... | 9 | 6 | 6·59 |

The interval between the two observations is 3 hours 58 minutes 55 seconds, during which time the star passed over a certain horizontal angle, which is defined by the two observations upon the divided limb of the transit-theodolite; and if the verniers are made to coincide with the middle point, or half the horizontal angle, taking care not to disturb the instrument in position, the vertical hair in the telescope will indicate the direction of the astronomical meridian, which may be permanently set out upon the surface. This mode does not involve by necessity a consideration of latitude, longitude, nor a previous determination of time. However, it is necessary to obtain a proof of the accuracy of the operation, and as the time was noted at each altitude by a chronometer, we have independent means of proving the previous operation on the following night. To perform this, the transit-theodolite should be planted over the same station, nicely adjusted, and the vertical hair directed to the same star some 10 or 15 minutes before its meridian passage, and kept upon it until an assistant gives notice that there are only a few seconds of the time to run, and when he gives the word "stop," the 9 hours 6 minutes 6·59 seconds will have elapsed, and the observation is concluded. The assistant should give the word "stop" about 2 seconds before the time has elapsed.

If the telescope be now brought down to the horizontal, its vertical hair should strike through the centre of the permanent mark previously fixed in the meridian. If it disagrees, an error has been introduced, and the operation should be repeated on following nights. Then, for the rate of the timekeeper we also have

| | Hrs. | Mins. | Secs. |
|---|---|---|---|
| The chronometer showed the difference of the star's return to the same altitude in the interval of 24 hours ... ... | 0 | 4 | 3·37 |
| The true difference of the time of the return of the star or acceleration in 24 hours is ... ... ... .. ... | −0 | 3 | 55·91 |
| The difference in time, and the loss of rate of the chronometer in 24 hours is ... ... ... ... ... ... ... | 0 | 0 | 7·46 |

This is one of the most interesting, facile, and accurate modes known to the writer, of setting out the astronomical meridian, as also of determining the rate of a timekeeper, and it may be employed at any time when the atmosphere is clear and the star has sufficient altitude. Naturally this implies that the operation is better performed on a dark than on a light night.

Independent of the constant personal-error equation, in reading finely-divided mathematical scales, the probable accidental error in appreciating the exact instant of contact of the star with the vertical hair in the telescope would not exceed more than 0·080 to 0·094 second of time; but when observations are made upon the larger planets and the sun or the moon, it would exceed that quantity. When a star is observed, this error is too insignificant to affect the time or the position of the meridian. This method seems therefore to leave nothing to be desired in point of simplicity and precision. It should be noted that any change of the atmosphere during the interval of time which elapses between the two observations would affect the second altitude, requiring the application of a very small correction; but it would be too insignificant to affect the middle point or direction of the meridian in a sensible degree, and, except for excessively fine geodotic surveying-operations, may be neglected.

The rule by the sun is as follows:—To the logarithm of half the change of the declination of the sun during the interval of the observations, add the logarithm secant of the latitude, and also the logarithm cosecant of half the interval of time elapsed, con-

verted into arc, the sum, minus 20 in the index, will be the logarithm of the correction in seconds of space.

Assuming, therefore, that (D′ − D) is the difference of the sun's declination during the interval of time between the two altitudes, and (T′ − T) is the interval of time itself, then, for the amount of correction, we should have ½ (D′ − D) sec. lat. cosec. ½ (T′ − T).

The elements required are the latitude, 50 degrees 0 minutes 0 second; interval of time, 4 hours 30 minutes 0 second. Half the interval is 2 hours 15 minutes 0 second. Measured horizontal angle between the altitudes, 146 degrees 16 minutes 20 seconds. The half, or middle point is 73 degrees 8 minutes 10 seconds. Hourly change of sun's declination is 30·70 seconds, and during half the interval is 69·075 seconds.

| | | | |
|---|---|---|---|
| Also we have ½ (D′ − D) = 69·075 seconds, and ... | log. | = | 1·8393209 |
| Latitude is 50 degrees 0 minute 0 second, and ... | log. secant | = | 10·1919325 |
| And ½ (T′ − T) = 2 hours 15 minutes 0 second = 37 degrees 30 minutes 0 second, and ... ... | log. cosecant | = | 10·2155529 |
| The correction required is 176·525 seconds, and | log. | = | 2·2468063 |
| also 176·525 seconds equals 2 minutes 56·525 seconds. | | | |

| | Degs. | Mins. | Secs |
|---|---|---|---|
| The direction of the middle point, or meridian is ... ... | 73 | 8 | 10·000 |
| The correction due to change of declination is ... ... ... | 0 | 2 | 56·525 |
| The true direction of the meridian is ... ... ... ... | 73 | 5 | 13·475 |

The instrument should be made to indicate 73 degrees 5 minutes 13·475 seconds; the vertical spider-line in the focus of the telescope would then point out the direction of the meridian. It must be remembered that when the sun is advancing northwards, the middle point, or apparent meridian, is too much to the west by the amount of the correction, and when the sun is receding from the north pole, the contrary is the case.

No more advantage would accrue from plotting the workings of a mine from the true meridian-line than from the first line formed along and by the drift-road leading from the shaft into the mine, and which could be prolonged throughout the plan—as previously noted—or if the general workings ran nearly at right angles to this line, then a co-ordinate base-line at right angles to the first line could be adopted; in fact, either the one or the other is preferable, especially the first, because it is a permanent line

forming a portion of the mine itself, and also of the survey, and it is moreover the line to be reproduced upon the surface by Mr. Beanlands' system of connecting the two, and should, consequently, be made a permanent base-line, to which all underground workings, surface boundary-lines, and other objects should be referred. The difference in horizontal angle between such a base-line and the magnetic and the true meridian is ascertained by a mere inspection upon the plan.

The writer is in accord with Mr. Ramsay's opinion that the true meridian is not "really necessary for keeping a colliery-plan,"* and could only be considered as an ornament.

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Mr. A. L. Steavenson (Durham) wrote that he was pleased to notice in Mr. Hoskold's remarks a further weighty confirmation of the useful purpose which his paper had served in bringing before the members all that could be said on so important a subject. Since his paper was read, Mr. Arthur Beanlands had died, and the members had obtained all that the latter's long experience enabled him to afford them. It was partly with this view that his paper had been written; the writer would have very much preferred that Mr. Beanlands had himself dealt with the subject, but it may be said to have forced his hands and so effected its object.

Only on the question of the necessity for a true meridian-line on each mine-plan does the writer differ from Mr. Hoskold; because, although in all important mines there may be a surveyor who is sufficiently skilled to deal with a theodolite, it is a wellknown fact that there are many small mines where a theodolite is never seen; and even where the main lines and places adjoining boundaries are surveyed with the theodolite, there are always lesser internal surveys, and winning-places, turned away with the compass. To meet such cases, and they are very common, it is absolutely necessary that in practice, a true north line should be drawn on the mine-plan, and another on the surface, to enable the correctness and variation of the needle to be tested. Mining engineers have not only to deal with what is theoretically right, but to meet the demands of everyday practice.

* *Trans. Inst. M.E.*, 1895, vol. x., page 60.

He (Mr. Steavenson) was aware of the difference between the mean solar day and the sidereal day, and assumed that any engineer dealing with the question would be obliged to recognize it.

The PRESIDENT (Mr. J. G. Weeks) had pleasure in proposing a vote of thanks to Mr. H. D. Hoskold for his interesting contribution to the *Transactions*.

Mr. W. C. BLACKETT seconded the resolution, which was cordially approved.

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Mr. W. T. GOOLDEN read the following description of "The Type-printing Telegraph":—

# THE TYPE-PRINTING TELEGRAPH.

By W. T. GOOLDEN.

The type-printing telegraph (Steljes & Higgins patent) substitutes for the receiving-dial of the Wheatstone ABC telegraph (on which the messages are read by watching the revolving needle as it stops for an instant at individual letters or signals), a printing receiver, in which the message is received upon a tape, independently of the presence of any person at the receiving-end of the line, and also provides a duplicate of the message printed on a corresponding tape at the sending-end. There being no operator at the receiving-end, only one person is concerned in the transmission of a message, and therefore the responsibility for any error in transmission cannot be made the subject of a dispute. At the same time, since the message appears letter by letter on his own tape in front of the operator while he is transmitting it, nothing but extreme carelessness can prevent him from discovering and rectifying at once any error that he may make.

The points of merit which gave such great popularity to the original Wheatstone ABC telegraph-instrument were:—(1) It did not require batteries; (2) it could be manipulated by any person of ordinary intelligence with very little practice; (3) as the instrument required a very small current and the magneto-generator (commonly called the communicator) was of fairly high electromotive force, its signals could be transmitted over considerable lengths of wire. Its defects were:—(1) The necessity of an attendant at the receiving-end to read and transcribe the message, which defect it shares with the telephone; and (2) the low speed of working, namely, about 20 to 25 words a minute; a defect which was very much intensified if the person sending the message worked faster than the person receiving it could read it, since this necessitated much repetition and consequent delay.

When the telephone was introduced, a great advantage in speed was obtained by speaking instead of telegraphing; and since the Wheatstone ABC instrument afforded no greater guarantee of accuracy than the telephone, a large number of the former instruments were abandoned, both on private lines and in the public service. In more recent times, however, people who are in the habit of transacting business by wire have felt the want of some means of ensuring accuracy and reliability in their messages, which can only be obtained by some form of recording-instrument. Everyone appreciates the speed and facility afforded by the telephone for negotiating a bargain, but these advantages only render more apparent the need of speedier means of confirmation than the ordinary postal service.

Another point which arises in this connection is the difficulty of getting a message through on a telephone-wire, when the correspondent at the other end happens to be out of the way at the time of the call. On trunk-lines, especially where the call is confined to the limits of 3 to 6 minutes, and where considerable delays arise constantly in waiting for a line, it is a great annoyance not to find one's correspondent ready at the critical moment. This annoyance could be entirely abolished by sending a short message through on a tape the moment that communication is established.

These advantages are obtainable by the use of the printing telegraph-recorder. Retaining the simplicity of manipulation of the old form of Wheatstone ABC instrument, it gives a permanent record at both ends of the line simultaneously. By improvements made in the transmitter or communicator, messages can now be sent over greater distances of line, and not only can the instruments be worked over telephone-circuits, but it is easy to arrange that the telephone and the telegraph be worked simultaneously and independently on the same circuit, neither instrument affecting the other.

Experiments made on the Post Office telephone-system in the North of England show that it is possible to use this system of telegraphy on the telephone-lines, through the exchanges, without altering in the least any of the existing signals or ordinary working of the exchange.

One use in particular should commend itself to the public, especially in the North of England, if the Post Office will allow of it. It is this:—Many private houses and business-firms are accustomed to send and receive their telegrams to and from the Post Office by telephone. Though this plan is preferable to that of using messengers, it has the drawbacks that there is a risk of inaccuracy with no certainty of being able to fix the responsibility for mistakes on the proper person, and also that privacy cannot be assured. If the present telephone-lines were fitted with these printing instruments in addition to the telephones, and there were also instruments at the Post Office, telegrams could be sent and received with accuracy. Privacy can be obtained by keeping the recorder in a case fitted with lock and key.

Another important use of the instrument is the simultaneous despatch of messages to a number of stations from one centre. For instance; an alarm of fire, giving the exact place and time of outbreak, can be sent to all fire-brigade stations in a district without loss of a moment; or a special message can be sent to a number of police-stations simultaneously. A large number of these instruments are used in this way in London. It can also be used for distribution of news, to subscribers to an exchange, who would all receive the message at the same time, within a minute or two of its reception at the distributing centre. The subscribers might live anywhere within a radius of from 10 to 20 miles of the exchange, and the news would come through on to the tape, without the necessity of anyone being present to receive it.

These instruments are operated by a transmitter of the ordinary Wheatstone type, which sends into the line-circuit alternating currents of feeble power at the rate of about 2,800 alternations per minute. This form of transmitter is too well known to need description, but the main feature of it is that it sends a current into the line so long as the needle on the dial is moving, and that, when the needle is arrested by the depression of a key, the circuit is broken and remains so until the needle is released by the depression of another key and again commences to move. The type-wheel and the needle of the transmitter are arranged to advance simultaneously, one letter for each alternating current sent into the line. The recorder consists of two

FIG. 1.—THE TYPE-PRINTING TELEGRAPH.

distinct sets of mechanism, each driven through its own train of wheels by a weight or spring.

The detailed operations of the recorder are illustrated by the accompanying figures. Fig. 1 is a general view of the recorder and transmitter installed for working. Fig. 2 (Plate II.) shows a plan of the type-wheel mechanism; Fig. 3 shows the escapement controlling the printing mechanism; Fig. 4 shows the printing mechanism and the unison-apparatus; and Figs. 5 and 6 show the change-over gear for the double type-wheel. $A$ is the rubber type-wheel, which is kept supplied with ink by the circular inking-brush seen in Fig. 1. $B$, Fig. 2, is an escapement-wheel, fast on its axis, $B^1$; this axis is driven through a coiled spring, $C$, from a pinion, $D$, which turns loosely round $B^1$, and is itself driven through a train of wheels by means of a weight or spring. The escapement-wheel, $B$, has two rings of teeth, staggered round its circumference. A tooth at the end of the rocking-arm, $G$, engages first with the teeth of one ring, and then with the teeth of the other. This rocking-arm carries the armature, $H^1$, of an electro-magnet, $H$. The back ends of the two cores of this magnet are coupled by a piece of iron, to the centre of which is fastened one pole of a permanent magnet, $I$. The other pole of this permanent magnet is made to rest in front of the armature, $H^1$, leaving sufficient room to allow of the armature being rocked.

When alternating currents are passed, in regular succession, through the coils of the electro-magnet, $H$, the polarity of one core is intensified and that of the other is reversed at each reversal of current. The armature, $H^1$, is thus rocked by being alternately attracted and repelled by each core, and it allows the escapement-wheel to advance step by step, carrying with it the type-wheel, in synchronism with the needle on the transmitter.

The current passes from $H$, through the coils of an electro-magnet, $K$ (Fig. 3), which controls the printing mechanism. When the current passes, this magnet attracts an armature, $K^1$, and is adjusted to be too sluggish to release the armature between the reversals of current, but does so when the circuit is broken. The armature, $K^1$, is carried by one arm of a lever, $L$, pivoted at $J$. The opposite arm of this lever carries two steel blades, $L^1$, and $L^2$. An arm, $M$, extending from the last spindle of the left-

hand train of wheels, carries a projection which rests against the blade, $L^1$, when $K^1$ is attracted to $K$, and against $L^2$ when $K^1$ is released, and as long as the current is passing in the line and the type-wheel is turning, $K^1$ is attracted and $M$ rests against $L^1$. When the current ceases, and the type-wheel stops in the desired position, $K^1$ drops and $L^1$ is lifted above the arm, $M$, which then makes an almost complete revolution and rests against $L^2$, until $K^1$ is again raised; then $M$ passes $L^2$ and rests against $L^1$. These operations are repeated each time that the circuit is closed and broken.

An eccentric, $M^1$ (Fig. 4), is fastened on the end of the spindle carrying $M$, and is embraced by a slot in the printing-lever, $P$, which carries the paper-roller. Each time that the circuit is broken and $M$ makes a revolution, $M^1$ raises the lever $P$ so that the paper is brought against the bottom of the type-wheel, and receives an impression of the character, which has been manipulated by the transmitter into that position. The paper-tape is passed over a roller, $R$, and held down by spring-blades, $S$. This roller turns freely on a pin fixed to the printing-lever, and carries at its back a ratchet. When the lever, $P$, is raised and carries the roller with it, the pawl, $V$, engages with this ratchet, and as the lever falls back, the paper is fed forward a small distance, ready to receive the impression of the next letter or character.

The rubber type-wheel is a double wheel, bearing two distinct circles of letters or characters, corresponding to the two circles on the transmitter-dial. The transmitter has two spacing keys opposite one to the other, and by the use of one or other of these keys either circle of the type-wheel may be brought into the printing position. This is effected by the mechanism shown in Figs. 5 and 6 (Plate II.). The double type-wheel is carried on an axis, $B^1$, so that it can be pressed along $B^1$ by a coiled spring, $E$, but can not turn around it. A small metal slide, $F$, passes through a slot in the axis, $B^1$, and in the same diameter as the two opposite spaces on the type-wheel. On $F$ is a small triangular projection $F^1$. The boss which carries the type-wheels carries also a small roller, $T$, which is pressed against $F^1$ by a spring, $E$. A pin, $Z$, prevents the slide from passing too far in one direction, and a link, $X$, controls its movement in the other direction. Whenever the type-wheel is arrested, by either spacing-key of the transmitter with the slide, $F$, in the vertical position, the

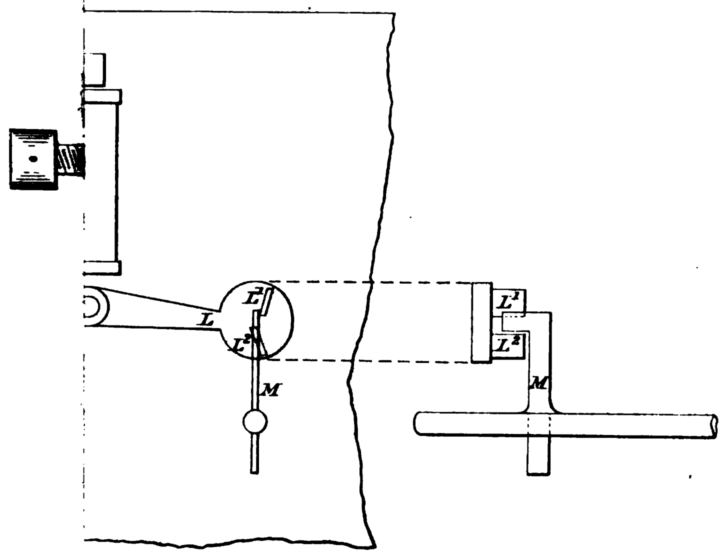
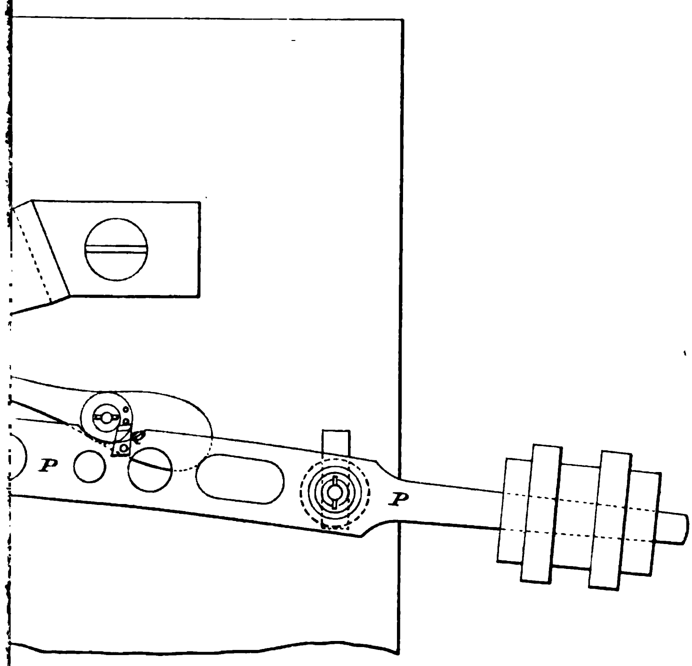



Fig. 3.—Elevation.




Elevation.

lever, $P$, is raised by the eccentric, $M^1$, and a small projection, carried by $P$, comes up against the end of $F$, and thrusts the type-wheel into a position on the axis, and brings the corresponding circle of characters over the paper, where they remain until thrust by the use of the other spacing-key.

A unison arrangement is employed in order to synchronize all the instruments on the line-circuit at the beginning of a message (Fig. 4, Plate II.). A stop-lever, $W$, is driven by friction from the axis of one of the train of wheels on the type-wheel mechanism. This friction is adjusted so that, if all the keys of the transmitter are raised and the type-wheel is allowed to make three complete revolutions without printing, the arm, $W$, rises high enough to engage with a pin, $W^1$, on the type-wheel axis, and holds the type-wheel in the position corresponding to the top spacing-key on the transmitter. The type-wheels of all the instruments on the line being held thus, the spacing-key is depressed and the circuit broken. The printing-lever is raised, and a projection carried on it knocks down the arm, $W$, by means of a pin, $Q$, and releases the type-wheels. All the instruments are thus set in unison with the transmitter. The arm, $W$, is always rising while the type-wheel is in motion, but it is knocked down each time that printing takes place, and it therefore never rises high enough to engage with $W^1$, except when (as mentioned above) the type-wheel is allowed to make three complete revolutions without printing, which never happens while a message is being sent.

These instruments, in contrast to the existing tape-machines in use in London clubs and hotels, require only a very slight current. The construction of the machine is exceeding simple, and there is very little wear of the moving parts; consequently the cost of maintenance is exceedingly small.

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Mr. A. L. Steavenson (Durham) said that the printing telegraph-recorder was invaluable to deaf persons, who could not use the telephone. It had also the great advantage of preserving a record of the messages, which could be registered by the instrument, when left unattended to; and confidential messages would be possible, if the instrument were placed in a

locked room or box. He had pleasure in moving a vote of thanks to Mr. W. T. Goolden for his interesting paper.

Mr. W. C. Blackett, in seconding the vote of thanks, said that Mr. Goolden, with the courteous assistance of the authorities of the Post Office telephone-department, had proved the practicability of using the printing-telegraph upon the same line of wire as that over which talking was being done, and the possibility of obtaining a printed record of transmitted messages at both ends of the wire.

The resolution was cordially approved.

# THE MINING INSTITUTE OF SCOTLAND.

## TWENTY-FOURTH ANNUAL GENERAL MEETING,

HELD IN THE HALL OF THE INSTITUTE, HAMILTON, APRIL 11TH, 1901.

MR. JAMES T. FORGIE, RETIRING PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The SECRETARY read the Report of the Council as follows:—

## COUNCIL'S REPORT.

The Council, in submitting their twenty-third annual report, embracing the proceedings of the Institute from April 12th, 1900, till this date, have to state that the Institute has been maintained in a fair state of efficiency during the year.

The members of the different classes at this date are as follows:—

| | |
|---|---|
| Honorary Members ... ... ... | 3 |
| Life Members ... ... ... | 8 |
| Life Associate Member ... ... ... | 1 |
| Members (subscription £2 2s.) ... | 153 |
| Members (subscription £1 5s.) ... | 206 |
| Associate Members ... ... ... | 21 |
| Associates ... ... ... ... | 11 |
| Students ... ... ... ... | 14 |
| Non-federated Life Member ... | 1 |
| Non-federated Members (subscription £1 1s.) | 19 |
| Non-federated Members (subscription 10s.6d.) | 12 |
| Total ... | 449 |

These numbers compare with those of last year as follows:—

| | | |
|---|---|---|
| On the roll at April, 1900 ... | | 454 |
| Added during the year ... ... | | 35 |
| Total ... | | 489 |
| Died ... ... ... | 8 | |
| Retired ... ... ... | 10 | |
| Cut-off through non-payment of subscriptions ... | 22 | 40 |
| At present on the roll ... | | 449 |

While there has been a gratifying number added to the roll during the year, it will be seen that the retirements from various causes exceed the additions. The following table shows the number on the roll at the date of each annual meeting during the past 16 years, with the additions and retirements in each year; from which it will be seen that the average number of retirements has been 37, or 7·6 per cent. of the whole, and the average number of additions has been the same.

| | | Number of Members. | | | |
|---|---|---|---|---|---|
| Year. | Added. | Died. | Retired. | Cut off. | On Roll. |
| 1886 | 47 | — | 5 | 14 | 481 |
| 1887 | 33 | 5 | 7 | 33 | 469 |
| 1888 | 56 | 5 | 5 | 28 | 487 |
| 1889 | 50 | 6 | 12 | 16 | 503 |
| 1890 | 43 | 3 | 13 | 27 | 503 |
| 1891 | 44 | 7 | 10 | 25 | 505 |
| 1892 | 77 | — | 3 | 33 | 546 |
| 1893 | 24 | 4 | 19 | 19 | 528 |
| 1894 | 32 | 5 | 20 | 54 | 481 |
| 1895 | 37 | 9 | 9 | 13 | 487 |
| 1896 | 27 | 2 | 6 | 14 | 492 |
| 1897 | 23 | 5 | 4 | 26 | 480 |
| 1898 | 25 | 4 | 10 | 24 | 466 |
| 1899 | 37 | 3 | 23 | 9 | 468 |
| 1900 | 12 | 7 | 4 | 15 | 454 |
| 1901 | 35 | 8 | 10 | 22 | 449 |
| Averages | 37 | 4 | 10 | 23 | 487 |

This table emphasizes the need of the roll being constantly augmented by the addition of new members.

The papers read and published during the year are:—

"Weight of Winding-drums for Deep Shafts." By Mr. Daniel Burns.

"An Indian Colliery and its Miners." By Mr. H. M. Cadell.

"An Ordinary Miner's Boring-machine adapted for Boring against Wastes." By Mr. Robert Martin.

"Hauling and Pumping Underground by an Oil-engine." By Mr. William Smith.

A lecture was given by Mr. Stirling, Government Geologist for Victoria, on some of the physical and geological features of that colony.

The annual excursion to Prestongrange colliery was largely attended, and was of the most agreeable kind. A description of the colliery is printed in the *Transactions.*

An interesting visit was paid on December 12th to the electric-lighting station of the Glasgow Corporation, and a short description of the installation also appears in the *Transactions.*

The report of your delegate to the Conference of Delegates of Corresponding Societies of the British Association for the Advancement of Science was read at the October meeting, and has also been printed in the *Transactions.* It is desirable that this Institute, through some of its members, should undertake such work as is indicated in that report.

The donations to the library, in addition to those by exchange, received during the year are as follows:—

| Donors. | Donations. |
| --- | --- |
| Mr. J. M. Ronaldson ... | ... Report of H.M. Inspector of Mines for West Scotland. District Statistics, Part I.; Labour, Part II.; Output, Part III. List of Abandoned Mines, 1900. |
| Mr. Bennett H. Brough | ... "Cantor Lectures on the Nature and Yield of Metalliferous Deposits." |
| Mr. Henry Aitken ... | ... "Iron and Steel Manufacture," by Mr. F. Kohn. |

The Treasurer's accounts shew that the financial condition of the Institute is very satisfactory.

There have been nine meetings of Council during the year.

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The report was unanimously adopted.

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The SECRETARY read the annexed Abstract of the Treasurer's accounts for the year duly audited, and it was adopted.

## The Treasurer in Account with The Mining Institute of Scotland
### For the Session 1900-1901.

| Receipts. | | | | £ | s. | d. |
|---|---|---|---|---|---|---|
| To Balance brought forward ... | | | ... | 235 | 2 | 0 |
| „ Subscriptions— | | | | | | |
| 12 Members, | Session 1899-1900 | ... | at 42s. 0d. | 25 | 4 | 0 |
| 6 „ | „ „ | .. | „ 25s. 0d. | 7 | 10 | 0 |
| 1 Associate | „ „ | ... | „ 25s. 0d. | 1 | 5 | 0 |
| 2 Students | „ „ | ... | „ 25s. 0d. | 2 | 10 | 0 |
| 189 Members, | Session 1900-1901 | ... | „ 42s. 0d. | 291 | 18 | 0 |
| 192 „ | „ „ | ... | „ 25s. 0d. | 240 | 0 | 0 |
| 21 Associate Members | „ | ... | „ 42s. 0d. | 44 | 2 | 0 |
| 9 Associates, | Session „ | ... | „ 25s. 0d. | 11 | 5 | 0 |
| 1 „ | „ „ | ... | „ 17s. 0d. | 0 | 17 | 0 |
| 12 Students | „ „ | ... | „ 25s. 0d. | 15 | 0 | 0 |
| 21 Non-federated Members | „ | ... | „ 21s. 0d. | 22 | 1 | 0 |
| 11 „ | „ „ | ... | „ 10s. 6d. | 5 | 15 | 6 |
| 2 Members, | Session, 1901-1902 | ... | „ 42s. 0d. | 4 | 4 | 0 |
| 1 „ | „ „ | ... | „ 21s. 0d. | 1 | 1 | 0 |
| 4 „ | „ „ | ... | „ 25s. 0d. | 5 | 0 | 0 |
| 1 Associate | „ „ | ... | „ 25s. 0d. | 1 | 5 | 0 |
| „ Subscription in arrear ... | | | ... | 0 | 1 | 0 |
| „ *Transactions*, &c., sold ... | | | ... | 8 | 18 | 2 |
| „ Rents of Hall ... | | | ... | 2 | 17 | 6 |
| „ Interest on Deposit Receipts ... | | | ... | 4 | 12 | 9 |
| „ The Institution of Mining Engineers, repaid ... | | | ... | 12 | 2 | 1 |
| | | | | £942 | 11 | 0 |

| Payments. | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| By The Institution of Mining Engineers ... | | | | 417 | 2 | 10 |
| „ Printing and Stationery ... | | | | 26 | 11 | 4 |
| „ Books and Bookbinding ... | | | | 11 | 5 | 10 |
| „ Bookcases and Alteration of Rooms ... | | | | 17 | 10 | 0 |
| „ Rents of Halls ... | | | | 18 | 16 | 6 |
| „ Gas and Assessments ... | | | | 3 | 1 | 7 |
| „ Stamps, Carriages, Telegrams, etc. ... | | | | 7 | 5 | 0 |
| „ Sundry Payments ... | | | | 5 | 3 | 3 |
| „ Cleaning Hall ... | | | | 5 | 17 | 0 |
| „ Expenses of Council ... | | | | 36 | 12 | 11 |
| „ Salaries ... | | | | 93 | 8 | 0 |
| „ Cash in the Bank ... | 287 | 1 | 2 | | | |
| „ „ in the Treasurer's Hands ... | 12 | 15 | 7 | | | |
| | | | | 299 | 16 | 9 |
| | | | | £942 | 11 | 0 |

Hamilton, March 28th, 1901.—Examined, compared with vouchers, and found correct.

WILLIAM WILLIAMSON,<br>THOS. STEVENSON, } Auditors.

Messrs William Williamson and Thomas Stevenson were thanked for their services as Auditors.

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The following gentlemen were elected by ballot:—

Associate Member—
Mr. James Borland, 23, Thomson Street, Kilmarnock.
Associate—
Mr. Alfred Davis, Lethbridge Colliery, Alta, Canada.
Student—
Mr. John Hutt, Keltyhill Road, Kelty.

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## ELECTION OF OFFICE-BEARERS.

The Chairman declared the following office-bearers duly elected for the session 1901-1902:—

President.
Mr. James S. Dixon, 127, St. Vincent Street, Glasgow.

Vice-Presidents.
Mr. John Gemmell, 10, St. Andrew Square, Edinburgh.
Mr. James Hamilton, 208, St. Vincent Street, Glasgow.
Mr. James Hastie, Greenfield Colliery, Hamilton.
Mr. Wallace Thorneycroft, Rockdale Lodge, Stirling.

Councillors.
Mr. Thomas Arnott, Fernbank, Newton.
Mr. Adam Brown, Allanton Colliery, Hamilton.
Mr. Robert W. Dron, 55, West Regent Street, Glasgow.
Mr. James Hardie, The Haugh, East Wemyss, Fifeshire.
Mr. Douglas Jackson, Coltness Iron Works, Newmains.
Mr. Robert M'Laren, Bonny, Uddingston.
Mr. John Menzies, Auchinraith Colliery, Blantyre.
Mr. David M. Mowat, Summerlee Iron Works, Coatbridge.
Mr. Michael Ross, Bog Colliery, Larkhall.
Mr. Thomas Thomson, Eddlewood Colliery, Hamilton.
Mr. William Williamson, Opal Cottage, Burnblea, Hamilton.
Mr. James Wyper, Townlands Colliery, Hamilton.

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Mr. Barrowman moved that the heartiest thanks of the Institute be given to Mr. Forgie for his services as President, which had been rendered with much diligence and success.

The President (Mr. J. S. Dixon) seconded the resolution, which was cordially approved.

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The President (Mr. J. S. Dixon), having been introduced by Mr. Forgie, read the following "Presidential Address":—

# PRESIDENTIAL ADDRESS.

By JAMES S. DIXON.

It is with mixed feelings of regret and pleasure that, after a lapse of 13 years, I have again the honour to be elected President of the Mining Institute of Scotland. I take it as a special honour to be chosen on this occasion, as it is with the particular object of filling an even more important position in the mining section of the Engineering Congress to be held in Glasgow this autumn. I trust that by the support of the members of the Institute our part in that great Congress may mark an epoch in the history of mining engineering. The regret to which I allude is occasioned by the blank places in our midst, caused by the death of many who took a deep interest in, and worked hard for, the Institute in past years, and many who from different causes are no longer much with us.

The members are no doubt aware that the Institute began in a small way in the year 1878, with Mr. G. B. Begg as President, and our retiring-President, Mr. J. T. Forgie, as Secretary. It was more formally constituted and the *Transactions* preserved and printed in May, 1879, when Mr. Ralph Moore became President, a position which he occupied with much acceptance for four sessions, till April, 1883; then he was succeeded by Mr. James McCreath, who presided till April, 1885; followed by myself till 1888; Mr. J. M. Ronaldson, till 1891; Mr. J. B. Atkinson, till 1894; Mr. G. A. Mitchell, till 1898; and Mr. J. T. Forgie, till this day.

Under the presidency of these gentlemen much useful work has been done, and many valuable papers contributed on the diverse matters embraced under the wide term of mining engineering and relative subjects.

I well remember the early days of the Institute, when most of the members were fired with youthful enthusiasm and

unquenchable thirst for knowledge of everything connected with mining. This feeling, which I think gave rise to the Institute, was coincident with the opening out of the Hamilton and district coal-field, which prominently brought forward many difficulties and new circumstances in mining that had to be encountered and overcome. The *Transactions* opened appropriately by a paper on ventilation, which was ably written and discussed at great length. This paper led to a long discussion on the merits of fans and elicited much useful information concerning them. The coal in the Hamilton new fields was exceedingly fiery, and at that time the Scotch gauze-lamp was used by the miners. This lamp has long ago been relegated to the shelves of museums; but when the safety-lamp committee of the Institute reported in 1882, the Mueseler protector, and other safety-lamps now universally used, were only just being introduced. About 1875, when the sinking at Bent colliery was approaching the coal, no engine-maker in the district knew anything about mine-fans, and I designed the one erected there, aided by information from an article on fans in *Spon's Engineering Dictionary*, published in 1871. Now every colliery engineering firm has drawings and patterns for fans, besides many improved types, the results of experience, so that a mine-owner has merely to select and order a fan of the capacity required.

In 1880, haulage began to be a subject of interest, and for some years it was frequently before the Institute in papers descriptive of the different systems. What is now an every-day occurrence was then a matter of experiment and interest, and much useful information was imparted by the papers which no doubt contributed to the comparative perfection of the wire-rope haulages that are now at work so universally.

During the sessions of 1881 and 1882, much useful information was collected and work done by the committees of the Institute on propping and safety-lamps. The latter to some extent led to the establishment of the Mueseler protector as the type of lamp for the fiery pits of Scotland, and a very serviceable lamp it has been. It will, I imagine, probably hold its own till it is supplanted by a handy electric lamp.

The first paper on improved screens was read in 1880, when the subject was just beginning to come into notice. In times of dull trade, there is an unceasing outcry by consumers against

dirt and small among the coal. When one sees the screening and cleaning arrangements of to-day, the wonder is that coal for outside markets was saleable at all, when passed unpicked over bar-screens. Scotch coal had then a wretched position on foreign markets, and Wishaw Main coal was the pseudonym for anything that was black. This arose from the Main seam being loaded and sold, with the different qualities all mixed together, as it came from the miners. By the adoption of cleaning-plants, the cannel, soft and splint coals in the seam are separated, and by itself, each forms a valuable gas, house or manufacturing fuel.

In 1885, the Institute inaugurated and held an Exhibition of Mining in Glasgow, which was an effort that can only be looked back upon with feelings of gratification by all who took part in it or visited it. It presented an object-lesson of a most practical and useful kind, it was a complete success both in that respect and financially, and reflected the greatest credit on all concerned.

In 1886, coal-washing began to be mentioned and was treated in a paper next session; these, and the growing importance of cleaning and washing, led to the Institute appointing a committee in 1889 to investigate and report on these subjects, which was done in a very exhaustive manner. Different parts of England, Wales and Scotland were visited, and much useful information, with elaborate drawings of the plants, was the result. I recommend this report to the younger members as worthy of their study. At that time, no correct information was available as to the best sizes of nuts, length and number of pulsations in washing-boxes, and many other details of what has now been perfected to a system.

In 1886, the use of electrical transmission of power was first brought before the Institute, followed by a more detailed and practical paper in 1889, and by some others in after years. This is a subject of great and increasing importance, and we are only on the threshold of it.

Coal-cutting machinery appears to have been comparatively neglected. The first paper was read in 1880, followed by others in 1891, 1893 and 1899.

Boring for minerals and sinking have been little more than touched upon, and this also applies to winding, pumping, subsidences, and many other subjects of interest. A few papers on the geological features of our own and other districts are

scattered through the *Transactions*: such subjects embrace a very wide and interesting field, which should be further explored.

In the session of 1892, the question of federation with other mining institutes in different parts of the country was brought before the Institute, and a report by a committee recommending that this should be done was adopted at the July meeting of that year, and was finally confirmed in December. The Institution of Mining Engineers met in Glasgow in 1893, and in 1894 our Institute ceased to publish its separate *Transactions*. At that time, considerable expectations were expressed that the papers read at meetings of other Institutes would form valuable subjects for discussion at our meetings, but this does not seem to have been taken advantage of. Many of the papers so read are of general interest, and although criticisms could only be answered through the medium of the *Transactions*, much good might come of a free discussion of many of them.

In my opening remarks, I mentioned the youthful vigour of the Institute 20 years ago. Many of the then members are those who still take a leading interest in its work, they are growing old along with the Institute, but during that time mining in Scotland has enormously increased, new circumstances and new men have arisen, and I wish to imbue the younger members with some of the youthful enthusiasm in getting and giving information to which I have referred. It is not to the veterans but to the rising generation that the Institute must look, to keep up the interest in its meetings and proceedings. Most people have an idea that, because they know a subject, or because it is one of usual practice, there is no use in bringing it before such an Institute as this; but these are just the things that give rise to most interest. The record of an endeavour, although a failure, is often as instructive as though it had been successful.

I would suggest as subjects for papers, sinking with heavy water; pumping water out of drowned coal-fields; mechanical stokers; working several seams back simultaneously (as applied in the Hamilton district recently); the effect on one another of working seams above or under others, and how long this effect lasts at different depths; subsidence and draw; crushes; size of stoops and width of rooms in workings at different depths; applications of electricity for pumping in shafts, dooks, etc., as well as for haulage and driving other machinery aboveground

and underground; comparisons of the expense and methods of handling outputs on old and new pitheads with automatic disloading cages, and self-acting gradients and creepers for moving the hutches into position; etc. These are only a few subjects that occur to me as of immediate interest, but others will present themselves to your minds, and from the constant change of circumstances to which mining is subject, new problems will arise.

Whether from a geological, engineering or commercial standpoint, mining is a subject of great national importance, and it behoves the members—as those in charge of the production of coal and other minerals on which the industrial existence of the country depends—to use every endeavour by mutual interchange of ideas to carry on our operations in the most efficient manner, both as regards safety to those employed and economy of production. It is only by this that we can hope to hold our own in the international industrial conflict, which seems to threaten us more and more, as time rolls on.

This address is somewhat of a retrospective reminiscence of the Institute, in which I have been interested since 1879, and my only apology for avoiding more technical questions in mining is that I may be expected to do this on an approaching, and not very distant occasion.

I cannot conclude without making reference to the great national loss sustained in the death of our late gracious Queen, whose life and character endeared her to every subject in the land and to none more than to those engaged in the mining industries of the country. During her reign the whole system of coal-mining and the treatment and uses of coal had been revolutionized. Great industries had been begun and prosecuted with success, and the condition of the people in the matters of living and general comfort had completely changed. Many members of our Institute have seen much of this themselves, but what a difference the late Queen must have observed in her 64 years of active life in the State, during which she interested herself in every section of the community, and most of all when any mining or other calamity occurred, when she was among the first to tender sympathy and help.

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Mr. James Hastie, in calling for a vote of thanks to the President for his able address, said that he, along with many others,

had watched Mr. Dixon's successful progress in mining engineering, and he was pleased that he had been elected, for a further term, to the honourable position of President.

Mr. Thomas Arnott seconded the motion, which was heartily adopted.

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## DISCUSSION OF MR. DANIEL BURNS' PAPER ON THE "WEIGHT OF WINDING-DRUMS FOR DEEP SHAFTS."*

Mr. Daniel Burns, replying to Mr. G. A. Mitchell's remarks, wrote that the useful load is included in his consideration, where $W$ is put as being equal to the weight of the moving mass, in this case taken as the weight assumed for the drums. The useful load appears again, separately, as equivalent to the force producing acceleration of the mass, simply because the size of winding-engine that would work such a drum, would be designed on the assumption of having to deal with that amount of load. The total moving mass was stated as being equal to $W$, and taken as the assumed weight of the drum for simplicity: the writer thinking that it would be perfectly clear that the term moving mass included all parts such as engine, rope, cages, etc., that had to be set in motion; the sum of whose weights, if referred to the periphery of the mean radius of the drum, might, with convenience, be taken as being represented by the weight stated in his paper. Whether the masses of the various moving parts be grouped or taken separately, the ultimate result will be the same, and will show that lightness of parts is essential to economy.

Mr. Geo. A. Mitchell (Glasgow) wrote that Mr. G. L. Kerr stated "that Mr. Burns was correct in taking the time of acceleration and retardation as being equal,"† but he does not give any reason for his opinion. He did not see any necessary connection between the two, as the rate of acceleration will vary with the power of the winding-engine, while the rate of retardation remains constant, leaving friction out of account. Mr. Burns seemed to be of this opinion, as he stated that "if a winding-

* *Trans. Inst. M.E.*, 1900, vol. xx., pages 49 and 154.

† *Ibid.*, page 154.

engine of sufficient size be erected, the necessary velocity may be imparted to the heavier drum in the shorter time."* It might be that in practice the two were nearly equal, but he had not gone into this question. In any case, the main argument of the paper was not affected. Mr. Kerr was right in saying that the total weight to be put in motion included the weight of the winding-drum, pulleys, etc. The pulleys, etc., also affected the question of retardation, so that the problem became very complicated, when everything was taken into account.

The PRESIDENT (Mr. J. S. Dixon) reminded the members that he had contributed a paper on this subject.† The drum which was then described was now at work at Bent colliery, and had proved most successful. He had gone into the question, not so much with the intention of dealing with the weight of drums, but with the object of indicating the benefit derivable from using spiral drums. By a series of diagrams he shewed clearly that the spiral drum was of considerable advantage. Generally, however, as a result of his investigations, he had come to the conclusion that for a deep pit, a heavy load and quick winding, an ordinary parallel drum, with a balance-rope below the cage, was the best. He knew, from personal knowledge, that heavy drums were most wasteful of power and of steam in raising coal. Drums of that description were to be avoided. They should rather be built on the open-work system and made as light as possible.

Mr. JAMES HASTIE said that, speaking from experience, he would not recommend colliery-managers to use conical or spiral drums.

The discussion was then closed, and Mr. Burns was awarded a vote of thanks for his paper.

* *Trans. Inst. M.E.*, vol. xx., page 51.

† *Trans. M.I. Scotland*, 1879, vol. i., page 77.

# NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

## GENERAL MEETING,
HELD AT THE GRAND HOTEL, HANLEY, JANUARY 14TH, 1901.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

ORDINARY MEMBERS—

Mr. THOMAS ASHWORTH, Junior, Glebe Colliery, Fenton.
Mr. F. L. CORK, Northwood Colliery, Hanley.
Mr. WM. HILL, General Manager, Midland Coal and Iron Co., Ltd., Apedale.
Mr. JAMES LYON, Heron Cross, Fenton.
Mr. WM. MORDY, 182, Waterloo Road, Cobridge.
Mr. J. G. PATTERSON, Miller Street Works, Manchester.
Mr. JOS. TURNER, Lismore Terrace, Kidsgrove.

ASSOCIATE MEMBER—

Mr. E. G. J. HARTLEY, Apedale Hall, Newcastle-under-Lyme.

ASSOCIATE—

Mr. SAMUEL PLATT, Rookery Pit, Bignall End.

STUDENTS—

Mr. HARDY BRIDGETT, Surveyor, Jammage Colliery.
Mr. G. LINDAY, Fenton Hall, Great Fenton.
Mr. D. THOMSON, Surveyor, Apedale Offices, Newcastle-under-Lyme.
Mr. J. P. WINSTANLEY, Chatterley-Whitfield Collieries, Tunstall.

## DISCUSSION OF MR. W. H. HEPPLEWHITE'S PAPER ON "THE HEPPLEWHITE TAPERED PIT-PROPS AND BARS."*

The PRESIDENT (Mr. W. N. Atkinson) said that the idea of the process of tapering one end of the post was to allow the timber to yield to the sinking roof, so that instead of breaking, the post

* *Trans. Inst. M.E.*, vol. xix., pages 8 and 106; and vol. xx., pages 214 and 264.

would burr or fuzz up the tapered portion. It appeared that certain mining-engineers had tested the system and found benefit from the tapered posts. He was not aware that any systematic trial of the system had been made in North Staffordshire, but it seemed to him a matter of some importance and worthy of the attention of colliery-managers.

Mr. J. C. Cadman said there was no doubt that tapering added very greatly to the life of props in certain mines. He was surprised that Mr. Hepplewhite had taken out a patent for tapering props, as he remembered tapered props being used many years ago in North Staffordshire. In the Seven-feet Bambury workings nearly all the props were tapered, for the reason given by Mr. Hepplewhite—to allow the roof and floor to settle without breaking the props. He thought that Mr. Hepplewhite would find it difficult to maintain a patent for a system which had been adopted more or less at many collieries in England. Mr. G. L. Kerr had stated in December, 1898, that "when the pavement is hard and slippery the props are often pointed, so that they will crush up when the pressure comes upon them."* Mr. Sawyer, in his *Accidents in Mines*, alluded to props being sharpened for the same reason. The members were indebted to Mr. Hepplewhite for having brought the subject forward, because when they had a hard floor and roof the effect of weakening the top and bottom of the props would be to add to their life, by allowing the roof and floor to give, without breaking the prop in the middle.

Mr. W. Statham said that he remembered the tapering of props being practised fifty years ago. It was the custom to use pointed props where the floor was hard. Mr. Hepplewhite laid down in his paper a rule as to the subsidence of the roof, and his idea seemed to be that the roof lowered from the face gradually and regularly. The weighting took place periodically, at intervals; it was known by the term "the weight coming on," and he thought that every practical mining-engineer would admit that the weight did come on intermittently and not uniformly. He was surprised at the way in which Mr. Hepplewhite sought to obtain the ratio in which the roof subsided. Mr.

* *Trans. Inst. M.E.*, vol. xvi., pages 234 and 235.

Hepplewhite said he measured from the face of the floor to the roof and at given distances, and that the roof became depressed at a given rate. Now it was wellknown that the floor often rose; consequently, if Mr. Hepplewhite trusted to such measurements his conclusion must be unsatisfactory, because the floor rose in much the same ratio—in fact, taking the Red Shagg seam, the floor was raised in greater ratio than the depression of the roof. Another contention in the paper was that by using tapered props it caused the face to work better, brought the weight uniformly on the face, and aided the collier in his work. He (Mr. Statham) thought that a prop sustaining 34 tons would cause the face to work better than a tapered prop which would only sustain 15 tons. He had known cases where colliers had neglected packing, and had not been able to earn their wages like other men who attended to the packing. Mr. Hepplewhite had done service to the mining community by bringing this matter forward; but, so far from the tapering being a new system, it was an old one, and had been practised extensively, and tapered props would be unsafe in some mines.

Mr. E. B. Wain remarked that the experiments of Mr. Hepplewhite had been made in flat, or comparatively flat, mines, where the workings were entirely on the longwall plan and over tremendous areas, and they could trace a regular rate of sinking of roof under those circumstances. In some of the large Nottinghamshire and Derbyshire collieries it was remarkable that at certain distances they could estimate the sinking to an inch. Mr. Hepplewhite had arrived at his conclusions in the mines referred to; whether he could reach the same results in steep mines was another matter.

Mr. J. C. T. Raspass said he could not quite agree with the statement that the weight on the face would be assisted by the props, and he was of opinion that if the packing were efficient the weight would be thrown on the face.

Mr. Wain said that undoubtedly the most efficient method of working coal was to build good packing and to use strong timbering.

The President (Mr. W. N. Atkinson) observed that there were many points in the method of working, which might affect

the results, and different conclusions were probably due to varying conditions. It was quite possible in a flat seam with a good roof, worked with a longwall face, that there was a regular and systematic settling-down of the roof behind the face, and that settlement might be regulated. Then, on the other hand, in a seam worked by bord-and-pillar, or a short face, the roof might settle in a different manner, and the same observations could not be made under that system of working, and a different roof might have a different effect on the way in which the pressure affected the face. Mr. Hepplewhite had devised a systematic application of tapered props, and as far as his (Mr. Atkinson's) experience went, he had not known of any place where it had been previously adopted on a a large scale. If it ever had been, one would have thought it was being overrated now, or otherwise it would not have dropped out of use. The use of tapered props appeared to be one of economy rather than of safety. In his opinion, the question of timbering and packing was deserving of more attention than it received, not only on the ground of economy, but from the point of safety. There were too many accidents by falls. In the year 1900, there were 495 men killed by falls of roof and side in this country, a larger number than had ever been recorded in one year. He was sorry to say that in the North Staffordshire district there were 26 fatal accidents in the year, and one death had to be added to those in 1900 as the result of a fall during the preceding year. So that in 1900 there were 27 deaths from falls of roof and side, a number considerably higher than the average for previous years. It was discouraging, after so many discussions and propositions with regard to timbering, to find that the past year was worse than usual for falls of roof and side.

# NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE GRAND HOTEL, HANLEY, MARCH 11TH, 1901.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

## DEATH OF H.M. QUEEN VICTORIA.

The PRESIDENT (Mr. W. N. Atkinson) said that the members would wish to join in the expression of the great national grief occasioned by the loss of their great and good Queen. Queen Victoria was on the throne before most of the members were born, so that all their lives had been spent under her sovereignty, and they were all so thoroughly acquainted with her great wisdom and virtues that he need not for a moment enlarge on the universal grief caused by her death. As loyal subjects they also wished to congratulate His Majesty King Edward VII. on his accession to the Throne.

He moved that the following vote of condolence and congratulation should be sent to His Majesty, King Edward the Seventh:—

## To the King's Most Excellent Majesty.

May it please Your Majesty,

We, the Members of the North Staffordshire Institute of Mining and Mechanical Engineers, Your Majesty's most dutiful and loyal subjects, beg humbly to present to Your Majesty the expression of our sincere condolence on the death of Her Majesty Queen Victoria, our late beloved Sovereign.

We also beg respectfully to congratulate Your Majesty and Her Majesty Queen Alexandra on your accession to the Throne, to assure Your Majesties of our unswerving loyalty and devotion, and to hope that Your Majesty may have a long and prosperous reign.

The vote was agreed to, every member standing while the resolution was being read.

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The minutes of the previous meeting were read and confirmed.

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The following gentlemen, having been previously nominated, were elected:—

ASSOCIATE MEMBER—

Mr. THOMAS TAYLOR, Rosendale, The Brampton, Newcastle-under-Lyme.

ASSOCIATES—

Mr. JOHN MONTGOMERY, Under-manager, Crackley, Silverdale.

Mr. GEORGE SHENTON, Under-manager, Church Street, Silverdale.

STUDENT—

Mr. THOMAS JOHNSON, junior, Mining Student, The Villas, Silverdale.

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Mr. E. P. TURNER read the following paper on "Coal-mining at Depths exceeding 3,000 Feet":—

# COAL-MINING AT DEPTHS EXCEEDING 3,000 FEET.

By PERCY TURNER.

In view of the rapid exhaustion of the thicker and more accessible seams of the British coal-fields, this subject is one of the greatest interest and importance. In the natural order of events, the best and more accessible coal is the first to be worked, and nearly all the coal hitherto raised in this country has been taken from the most valuable seams. Vast deposits of excellent and available coal remain, but a preference will continue to be given to the best and cheapest worked beds.

The question of the depth at which coal can be mined may be discussed under four headings:—(1) Increase in temperature; (2) increase in pressure; (3) winding difficulties; and (4) increased expenditure.

(1) *Increase in Temperature.*—By far the most important obstacle to deep-mining is increase of temperature. We know that the influence of seasonal changes of temperature extends downward to a limited depth, varying in different latitudes. In this country, the temperature of the earth is constant at a depth of 50 feet and at that depth is 50° Fahr. Below this zone of constant temperature, the heat of the strata increases. The rate of increase is generally taken at 1° Fahr. for every 60 feet increase in depth; so that this assumption would give a rock-temperature of 115·8° Fahr. at a depth of 4,000 feet, and 99·2° Fahr. at a depth of 3,000 feet. The deepest borehole is that put down by the Prussian Government at Paruschowitz, in Upper Silesia. It reached a depth of 6,573 feet, and the rate of increase of temperature was 1° Fahr. for every 62·1 feet.

Table I., compiled by Prof. Everett, F.R.S., shews in a concise form the results of underground-temperature determinations in Great Britain, collected by the Committee of the British Association, up to 1882.

The observed temperature at the face of the Saint Gothard tunnel, after firing shots, was 95° Fahr.* The highest temperature at which work was carried on in the Saint Gothard tunnel was 90° Fahr., and this was considered to constitute the permissible limit for men.

TABLE I.

| Locality. | Depth. | Increase in Depth for 1° Fahr. |
|---|---|---|
| | Feet. | Feet. |
| Bootle Waterworks, Liverpool ... ... ... | 1,392 | 130 |
| Talargoch Lead-mine, Flintshire ... ... ... | 1,041 | 80 |
| Nook Colliery, Manchester ... ... ... ... | 1,050 | 79 |
| Bredbury Colliery, do. ... ... ... ... | 1,020 | 78½ |
| Ashton Moss Colliery, do. ... ... ... ... | 2,790 | 77 |
| Pontypridd Colliery, South Wales ... ... ... | 855 | 76 |
| Astley Pit, Dukinfield ... ... ... ... | 2,700 | 72 |
| Wearmouth Colliery, Durham ... ... ... | 1,584 | 70 |
| Scarle Boring, Lincolnshire ... ... ... ... | 2,000 | 69 |
| Kingswood Colliery, Bristol ... ... ... | 1,769 | 68 |
| Radstock Colliery, Bath ... ... ... ... | 620 | 62 |
| South Hetton Colliery, Durham ... ... ... | 1,929 | 57½ |
| Rosebridge Colliery, Wigan ... ... ... ... | 2,445 | 54 |
| Boldon Colliery, Durham ... ... ... ... | 1,514 | 49 |
| Whitehaven Colliery, Cumberland ... ... ... | 1,250 | 45 |
| Salt-mine, Carrickfergus, Ireland ... ... ... | 770 | 43 |
| Slitt Mine, Weardale, Durham ... ... ... | 660 | 34 |

In a Cornish mine, Dr. Sanderson observed the high temperature of 103° Fahr. The men only worked 15 minutes at a time, and in all 3 hours a day, and appeared to be completely exhausted at the end of the work.† According to the observations of Prof. Church, on the other hand, men were working in galleries in the Comstock lode, in which the temperature of the air was 116° Fahr. and that of the rock 130° Fahr. In his paper on "The Heat of the Comstock Mines" he stated that "the rock in the lower levels of the Comstock mines appear to have a pretty uniform temperature of 130° Fahr.," and again "the surface of the rock exposed to the air of the drift was found to be about 123° Fahr., the experiment being made near the header or end of the drift. The air itself was found to show considerable uniformity, when its temperature was taken under circumstances that were at all similar. In freshly opened ground it varied from 108° to 116° Fahr. and higher tempera-

* *Cours d'Exploitation des Mines*, 1897, by Mr. Haton de la Goupillière.

† *Report of the Commissioners appointed to inquire into the Several Matters relating to Coal*, 1871, vol. ii., page 178.

tures are reported at various points, reaching in fact as high as 123° Fahr. in the 1,900 feet level of the Gould and Curry."*

A case in South Staffordshire may be mentioned as shewing the heat of the working-places. At the Norton Cannock collieries, Walsall, it was found necessary to drive a road in the Top Shallow coal-seam over a gob-fire in the Shallow coal-seam. Table II. contains the observations of the temperatures. The Shallow coal-seam is 303 feet from the surface and lies 39 feet below the Top Shallow coal-seam. It was found necessary to provide the workmen with a change of clothing, so that they could put on dry clothes when they had finished work. A supply of oatmeal and water was also provided for drinking purposes. Their rates also were about 25 per cent. higher than the cost in stalls, where the normal temperature of about 65° Fahr. prevailed.

TABLE II.—DAILY READINGS OF THERMOMETERS AT NORTON CANNOCK COLLIERY IN THE TOP SHALLOW COAL-SEAM, OVER A GOB-FIRE IN THE SHALLOW COAL-SEAM.

| Date. | | In Intake Airway. | In Stall-road, about 60 feet from Working-face. | In Working-face immediately after Coal was removed. | In Return Airway. |
|---|---|---|---|---|---|
| 1899. | | Degs. Fahr | Degs. Fahr. | Degs. Fahr. | Degs. Fahr. |
| August | 22. | 64 | 71 | 86 | 80 |
| ,, | 23. | 64 | 70 | 94 | 80 |
| ,, | 24. | 64 | 70 | 93 | 80 |
| ,, | 25. | 65 | 71 | 95 | 81 |
| ,, | 26. | 65 | 71 | 104 | 84 |
| ,, | 28. | 65 | 71 | 96 | 83 |
| ,, | 29. | 65 | 70 | 96 | 81 |

The question of maximum temperature depends in a great measure upon the hygrometric conditions of the air. It appears that if the mine-air is sufficiently dry to admit of free evaporation from the bodies of the workmen, a considerably higher temperature could be endured than in an atmosphere having the ordinary humidity of a mine. On the other hand, in certain circumstances, the mine may become dry and dusty, and in collieries dangers would arise from the explosive nature of dry coal-dust. This consideration requires attention, though in North Staffordshire it is not the general custom to water the roads; at great depths, however, to ensure safe working, watering may become absolutely necessary. The limit of depth will then soon be determined, as men cannot work in an atmosphere which is both hot and damp.

* *Transactions of the American Institute of Mining Engineers*, 1878, vol. vii., pages 46 and 47.

Table III. contains hygrometric observations in coal-mines compiled by the Royal Commission.*

TABLE III.

| Name of Mine. | Place of Observation. | Depth. | Distance from Downcast Shaft. | Dry Bulb. | Wet Bulb. | Relative Humidity, 100° being saturation. |
|---|---|---|---|---|---|---|
| | | Feet. | Feet. | Dgs. Fh. | Dgs. Fh. | |
| Rosebridge Colliery ... | Face of a Level | 2,391 | 207 | 71 | 64½ | 68·3 |
| Do. ... | Do. | 2,391 | 309 | 72½ | 65½ | 66·8 |
| Do. ... | Do. | 2,391 | 909 | 75 | 68 | 68·1 |
| Pendleton Colliery ... | Working-face | 2,064 | 5,241 | 81 | 73 | 66·5 |
| Do. ... | Do. | 2,214 | 2,181 | 77 | 69 | 64·8 |
| Astley Pit, Dukinfield | Do. | 2,216 | 1,770 | 73 | 69 | 80·7 |
| Astley and Tyldesley Colliery | Face of a Level | 1,200 | 6,105 | 69 | 69 | 100·0 |
| Bank Colliery ... | Working-face | 900 | 360 | 68 | 67 | 94·7 |
| Low Side Colliery ... | Do. | 492 | 1,758 | 60 | 60 | 100·0 |
| Anderton Hall Colliery | Face of a Level | 900 | 1,800 | 63 | 62 | 94·3 |
| Bradleyfold Colliery ... | Working-face | 540 | 4,560 | 70 | 69 | 94·8 |
| Wynnstay Colliery, North Wales | Do. | 1,173 | 1,833 | 67 | 66 | 94·6 |
| Hafod Colliery ... | Do. | 1,815 | 585 | 75 | 73 | 90·4 |
| Do ... | Do. | 1,452 | 1,170 | 72 | 70 | 90·0 |
| Clifton Hall Colliery... | Do. | 1,640 | 3,786 | 69 | 63 | 70·0 |
| Ryhope Colliery* ... | Do. | 1,560 | 8,286 | 73 | 71 | 90·2 |
| Seaham Colliery ... | Do. | 1,995 | 6,600 | 78 | 67 | 60·3 |

* Under the sea.

Spontaneous combustion will also have a great bearing on limiting the depth of coal-mining. Coal begins to absorb oxygen at 100° Fahr. as an average and does so increasingly as the temperature rises, and so we get an increased liability to gob-fires where the rock-temperature would be naturally hgh.

The best means of rendering the temperature fit to work in is to keep the air as dry as possible and to cool it. It might be feasible to make use of liquid air, or at any rate of compressed air. It would not be advisable to cool the air in the shaft, especially if water were present, because of the formation of ice; but it would be quite possible to place the liquefying apparatus at some distance from the shaft in the workings. The cooling apparatus would, of course, be an additional expense.

(2) *Effect of Increase in Pressure of the Rocks.*—Several years ago, Prof. G. H. Darwin and Dr. Isaac Roberts conducted a series of independent experiments to prove the frictional resistance between such small bodies as sand, grain, peas, etc. They both arrived at very similar conclusions and results. Dr. Roberts

* *Report of the Commissioners appointed to inquire into the Several Matters Relating to Coal*, 1871, vol. i., pages 86 and 87.

wished to determine directly the pressure of grain stored in bins (which are built 10 to 12 feet across and about 50 to 80 feet high). He arrived at the conclusions that (1) the pressure on the bottom ceased to increase before the depth of 2 diameters was reached; (2) the lateral pressure ceased to vary after a depth of 3 diameters, and in both cases the pressure may be considered as constant per unit of area at any point above that height. He concluded that this was due to the fact that the grains formed "a self-supporting parabolic dome held in position by friction." Practice shews that pressure does not increase in the same ratio as the depth, for pillars are not made so much larger at deep levels than in shallower mines; and the timbering, though requiring greater care, does not require much more attention and is not more costly in proportion in deep than in shallow mines.

The effect of increase of atmospheric pressure on the men does not require serious consideration. Experience shews that men can work at a depth of 50 feet in water or under a pressure of 37½ pounds per square inch; and this pressure is equivalent to a depth of 20,000 feet below sea-level.

The effect on machinery driven by compressed air is to increase the efficiency very slightly, the efficiency being proportional to the barometric pressure.

(3) *Increase of Winding Difficulties.*—It cannot be said that winding has much bearing on the limit of deep-mining. In the Lake Superior district, the Tamarack mine had, in February, 1896, the following shafts: No. 1, 3,232 feet deep; No. 2, 3,535 feet; No. 3, 4,450 feet; No. 4, 4,450 feet; and No. 5, 226 feet, which will be sunk to a depth of 4,700 feet. These shafts were all working, and the production of the Tamarack mine in 1896 was 575,960 tons of rock.*

From the statement of these depths alone, we see that a great many of the difficulties formerly connected with sinking and winding of deep shafts have now disappeared. Even if winding from great depths became impracticable in one stage, it would be possible to place one shaft below another and wind in stages. The economical working of the mine will, however, in a great measure depend upon the efficiency of the winding-plant and shaft-equipment.

* *Mineral Industry*, 1895, vol. iv., page 250; and 1896, vol. v., page 206.

(4) *Increase in Expenditure.*—In working mines at great depths, the cost of mining would increase. The increased cost would be chiefly due to the expenses connected with sinking, winding and ventilation.

With regard to sinking, the first outlay must necessarily become greater the greater the depth; the time taken would be longer, owing to the disposal of the dirt; and the cost of sinking also increases with the depth.

The cost of winding will be greater (1) by reason of a powerful plant and good shaft-equipment, and (2) by reason of the wear-and-tear of all moving parts.

It may be anticipated that wages will increase and hours will be shortened, owing to the heat in which the men will have to work. In collieries, liable to spontaneous combustion, experience has shewn, where the working-places become abnormally hot, that the workmen's wages must be enhanced.

As previously pointed out, the air circulating in the mine should be dried and cooled. It will also be necessary to use more powerful engines for ventilation.

The increased cost would be counterbalanced by the higher prices, which will be realized when coal is mined throughout the country from an uniform depth of over 3,000 feet. As the shallow mines become exhausted the rate of production will decline, and if the demand continues the selling price must rise.

(5) *Conclusions.*—The depth, then, to which coal-mines may extend depends upon human endurance of high temperatures, upon the possibility of reducing the humidity and temperature of the air, and upon the liability to gob-fires. The possible working of very thick seams (from 15 to 30 feet) appears to be less than seams up to 7 feet in thickness. Owing to the impracticability of completely packing horizontal thick seams, and the consequent necessity of supporting the roof with timber, and of finally allowing it to break down, instead of settling as it would if the goaf were packed, the effect of pressure becomes a serious matter. Indeed at 2,000 feet the difficulties are considerable, and at a depth of 3,000 feet, they would probably be such as to render packing impracticable.

The possible depth from which coals can be worked does not appear to be limited by any consideration of a mechanical nature.

With regard to drainage, it has been proved in most Cornish mines that the volume of water does not increase beyond a certain point, with increased depth. The comparatively shallow depths intercept most of the water, leaving only a fixed quantity to deal with in the sump. In the coal-fields, water is rarely, if ever, met with at great depths.

The limit of depth taken by Prof. E. Hull, in 1860, and by the Royal Coal Commission, in 1870, was 4,000 feet. Prof. W. Galloway, however, says "it is probable that a depth of at least 8,000 feet will be attained, even in those localities in which the rate of increase is as much as 1° Fahr. in 60 feet."*

(6) *Depths hitherto Attained.*—In the British Isles, little up to the present has been done in mining at a depth of 3,000 feet. The workings at the Pendleton colliery, Manchester, have attained the greatest vertical depth, namely, 3,474 feet; and the depths at the two collieries of Ashton Moss, near Manchester, and the Astley Pit, Dukinfield, are respectively 3,360 feet and 3,150 feet. There are, however, no shafts yet reaching to depths of 3,000 feet in Great Britain.

The deepest shaft in the world is the Red Jacket shaft of the Calumet and Hecla mine in the Lake Superior district, sunk to the depth of 4,900 feet. The next deepest are Nos. 3 and 4 shafts of the Tamarack mine, which are 4,450 feet. Other shafts over 3,000 feet deep are set forth in Table IV.

TABLE IV.

| | Feet. | | Feet. |
|---|---|---|---|
| Produits Colliery, Mons, Belgium | 3,937 | No. 1 Shaft, Tamarack Mine, U.S.A. ... ... ... | 3,232 |
| Viviers Shaft, Gilly, Belgium ... | 3,750 | Yellow Jacket Shaft, Comstock, Nevada, U.S.A. ... .. | 3,123 |
| Adalbert Shaft, Przibram, Bohemia ... .. .. ... | 3,672 | Marchienne Colliery, Belgium ... | 3,117 |
| No. 2 Shaft, Tamarack Mine, U.S.A. | 3,535 | St. André Shaft, Poirier Colliery, Belgium ... ... .. | 3,100 |
| Lansell Shaft, Bendigo, Victoria | 3,302 | Anna Shaft, Przibram, Bohemia | 3,100 |
| Viernoy Shaft, Anderlues, Belgium ... ... ... ... | 3,300 | Lazarus Shaft, Bendigo, Victoria | 3,024 |
| Maria Shaft, Przibram, Bohemia | 3,281 | | |

(7) *Economic Working.*—The economic working of collieries depends upon the equipment and plant, both aboveground and belowground. The depths to which a number of shafts have attained affords clear evidence that many of the difficulties have disappeared from sinking and winding.

* *Course of Lectures on Mining*, 1900, Subject VI., Ventilation, page 5.

*I. Shafts.*—The first consideration must be for the shafts. As a large output will be required and from so great a depth, high speeds of winding will be required. As sinking will require a big outlay, this should be economized by sinking few but capacious shafts. The shaft, therefore, should be of large area and truly vertical. The number of hooking-on places should be reduced to the least possible number, as time is lost by using intermediate hooking-on places. In order to maintain a large output, it might be necessary to wind in both shafts and this should be considered when sinking.

*II. Decking.*—The next consideration would be for changing the tubs in the cage. At great depths, it would be necessary to wind as much coal as possible each time, or to have the winding-engines running at a very high speed. When multiple-deck cages are used, the time taken in changing is a large item, and each stoppage means a shock to the ropes, which are thus subjected to greater stresses and wear out more quickly. As an example of the many-decked cage, that at Marchienne colliery, Belgium, may be mentioned. There are two winding-shafts, an elliptical one 8 feet 6 inches by 9 feet 3 inches, 3,000 feet deep, and a circular one 10 feet in diameter and 3,100 feet deep. Owing to the small diameter of the shafts, only one tub can be put upon a deck, and in order to maintain a large output, 10 and 12-decked cages are employed, thus avoiding a high-cage speed. The 10-decked cage weighs 7,700 pounds and the 12-decked cage 8,800 pounds. The dead weights with empty tubs are 11,000 pounds and 13,200 pounds. The time in winding is 120 seconds and the changing occupies 80 seconds with the 10-decked and 120 seconds with the 12-decked cage. These large cages necessitate the stoppage and starting of the engine 10 and 12 times.*

To overcome this delay an apparatus has been designed by Mr. Fowler for simultaneous decking.† A simpler method is to do all the changing by hand, but this requires more men, a set of men being required for each landing. It, however, does away with the machinery of the Cadeby type. Taking a 4-decked cage, there would be two landings at the pit-bank and underground. The first and third decks and the second and fourth

* *Trans. Inst. M.E.*, 1897, vol. xv., page 485.

† *Ibid.*, 1900, vol. xviii., page 478.

decks would be changed together, requiring only one movement of the engines while changing. At the pit-bottom, all the loads would be delivered on the top-landing and the loads for the bottom-landing would run into a small cage, which would drop the load on to the lower level. Another cage, on the other side of the shaft, would raise the empty tubs from the lower landing to the upper landing. These two cages would be connected by one rope and the loaded cage would raise the cage with the empty tubs. Automatic catches would be used in these cages. The roads should be arranged so that the full tubs would gravitate to the shafts, and the empty tubs to the haulage-roads.

*III. Catches for the Cage.*—With the ordinary forms of keps, if the cage is at bank, it cannot descend without being lifted off the props, as they cannot be moved when the cage is on them. This means a reversal of the winding-engine, and when a number of decks are changed two reversals are needed for each deck.

To avoid these reversals, the Stauss prop has been designed. This apparatus consists of two shafts fixed in bearings, the legs on which the cage rests are threaded on another shaft, which can swing about, but is attached by a link to another shaft. The shaft on which the legs are fixed is fixed to the lever-shaft by a toggle-joint. It is impossible for these props to move in an horizontal direction, as the toggle-joint is in a straight line when the lever is pushed over. When lowering, as soon as the toggle-joint is out of a straight line, the weight of the cage forces the props out of the way.

*IV. Ropes.*—The employment of cylindrical wire-ropes is limited to a certain depth, as a point is reached beyond which the rope will not support its own weight. Theoretically, tapered ropes have no such limit, but practically they have, owing to the method of construction. It is possible, however, to abolish wire-ropes altogether. This was done at the Epinac collieries, France, by Mr. Z. Blanchet, by means of a pneumatic arrangement. This was successfully employed for 10 years, but at the same time the results did not show it to be superior in economy to the system of employing wire-ropes. It proved, however, that the method was workable. It obviated any danger due to the use of ropes, and possibly improved ventilation. It may be

looked upon as one of the future methods of winding from great depths, when the use of wire-ropes may be almost impracticable.

*V. Winding-engines.*—The winding-engine certainly requires very careful consideration. The first question would be that of increasing the speed, and the best method would be to slightly increase the size of the cylinders and greatly increase the steam-pressure. It is a question whether the compound would be the most economical engine for winding. Steam, of a very high pressure, can now be obtained, and could be first used in the high-pressure and then in the low-pressure cylinder. The condensing apparatus should be worked by a separate engine, and probably the most economical method would be to connect all possible engines to a central condensation-plant.

The most important consideration with regard to the winding-engine is the drum. To accommodate the great length of round ropes, drums must be of large radius or of great width, for it is inadmissible to allow the ropes to overlap. The common practice is to use drums of large radius and driven by powerful engines. As an example, it may be well to give the dimensions of a large winding-engine built for the Tamarack Mining Company. It has 4 steam-cylinders, each 34 inches in diameter by 60 inches stroke: the main bearings are 24 inches in diameter and 15 inches long; the crank-pins are 12 inches in diameter and 15 inches long; the cross-head pins are 6½ inches in diameter and 12½ inches long; the drum is 25 feet in diameter, 24½ feet wide, and has a capacity for 6,000 feet of rope, 1½ inches in diameter; and the total weight of this engine is 531¼ tons, the drum and shaft weighing 128 tons. This engine will hoist the load from a depth of 6,000 feet at a speed of 4,000 feet per minute. The load is made up as follows:—6,000 feet of rope 21,800 pounds; cage, 4,200 pounds; two cars, 4,000 pounds; rock, 12,000 pounds; making a total of 42,000 pounds. The drum is cylindrical at the centre, but conical at the ends; hence, in starting, one rope unwinds from the cylindrical portion and the other winds on the smaller end of the cone, with the result that the actual balancing effect does not come into play until some way on in the wind.

As an example of a drum of small radius there may be mentioned the winding-engine now being erected at the Dolcoath mine, by Capt. Josiah Thomas. It was designed by Mr. Wm.

Morgans, who made use of a drum of small radius, and to overcome the angling difficulty he caused the drum to travel at right angles to the direction of the rope for a distance equal to the diameter of the rope at each revolution of the drum. The engine is an ordinary double-cylindered winding-engine bolted on a steel-girder frame, so as to be self-contained and independent of masonry foundations. The carriage is mounted on 20 railway-carriage wheels and runs on two tracks of 4 feet 8½ inches gauge. The principal dimensions are:—Two cylinders, each 24 inches in diameter by 60 inches stroke; the drum has a diameter of 10 feet and a length of 21 feet; and the shaft is 29 feet 6 inches long, the diameter in the centre being 14 inches, and 11 inches in the journals. The engine is built to work at a steam-pressure of 140 pounds per square inch. The total weight is about 150 tons, and the distance of travel is 17 feet. The ropes to be used will not exceed 5½ inches in circumference. The cages and loaded tubs are estimated to weigh 6¾ tons, of which the useful load will be 3 tons. The time allowed for the wind is 2 minutes, and for changing tubs, ½ minute.

With an ordinary cylindrical drum, unless some means are taken to counterbalance the weight of the rope hanging in the shaft, the engine is subjected to a large variation in load, especially in deep shafts. There are several ways by which counterbalancing may be effected.

The ordinary method consists of placing beneath the cages, a tail-rope equal in diameter to the winding-rope; one end of the rope being fastened to one cage and the other end to the other cage. A pulley, fixed in guides, is placed in the sump, and the balance-rope works round it. In some cases, no pulley is used, the rope being allowed to hang loose in the sump, with a beam passing through the loop, and two other beams at right angles to this one are placed one on either side of the rope to prevent it from twisting. By this means, perfect counterbalancing is obtained, as a factor is introduced equal and acting opposite to the winding-rope and gives equality at the beginning and end of the wind. The one objection urged against it is the greater weight put upon the capping of the winding-rope.

In another method, a balance-rope is employed, but instead of attaching it beneath the cage, it is connected to two other ropes which can be coiled upon a drum separate from the wind-

ing-drum. The balance-rope is equal in weight to both the winding-rope and the auxiliary rope, and is equal in length to the distance between the two cages when one is at the top and the other at the bottom of the shaft. Perfect counterbalancing would result, and no additional weight would be put upon the cap of the winding-rope. This, in conjunction with the fact that the balance-rope can be led into any part of the shaft and boxed off, constitutes the advantages over the former method.

The cylindrical drum in several collieries is displaced by the spiral drum, as an example of which may be mentioned that at Cadeby colliery. The larger diameter is 33 feet, the smaller diameter, 18 feet; the depth of the pit 2,289 feet; the weight of the drum is 80 tons; and the useful load is 4 tons of coal.

At a few collieries in Great Britain, the Kœpe system has been adopted: an example in this coal-field, at the Sneyd Collieries, Burslem, was described by Messrs. Gregory and Stobbs, about 12 months ago.*

(8) *Method of Working.*—In setting out the workings below-ground the principal consideration would be the prevention of spontaneous combustion, and the workings should be set out with the view of overcoming the dangers of gob-fires. It would be the best plan to drive out to the boundary at first before any drifting was done and to work the coal homewards. The drifts should be worked in panels, say, about 3 jigs in the panel. The road-ways should be driven narrow, so that if, when a panel was being worked, a fire broke out, it could be easily isolated, and the coal as easily recovered from the next panel.

The workings should also be set out with a view to employing mechanical coal-cutters, and the installation of a good system of haulage.

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Mr. G. A. Mitcheson said that the difficulties of winding from great depths increased at a far greater ratio than in direct proportion to the depth. The best way of dealing with the difficulty of deep winding was to erect a plant specially designed for winding from great depths. There was great diversity of opinion as to the design of winding-engine to be adopted. Some colliery engineers of great experience were in favour of a small

* *Trans. Inst. M.E.*, vol. xviii., page 450.

cylinder, and using high-pressure steam; others preferred a larger cylinder and a lower pressure of steam, and to use a compound and condensing engine. Some engineers were in favour of a parallel drum and a balance-rope, and others were in favour of a conical drum without a balance-rope. But the divergence of opinion depended upon whether they looked upon the subject strictly as to what was better mechanically, or allowed for arrangements which would increase the complications in the shaft. The method of sinking should be carefully arranged before sinking was commenced. A large shaft should be sunk with guides and two bowks instead of one: the sinking would then proceed at double the speed and the cost would also be decreased. He did not think that there would be any difficulty in ventilating deep mines.

Mr. B. Woodworth agreed with Mr. Turner, that the problem of winding at such depths was fairly well solved. Mr. Turner had not cited the use of the Kœpe system with the double rope, but there was one colliery in Belgium where it was adopted, and chain-attachments were used for adjusting the two ropes and caps, with safety-connections between the chains, so that in the case of one rope parting, the other rope carried the load until it was replaced, instead of falling to the bottom, as would have been the case with a fracture on the single-rope system. The latter danger was the most serious drawback to the simple Kœpe system of winding, so probably it might be possible to ascertain, before the discussion of the paper was resumed, if there had been found any practical difficulty, from rope-twisting or any other cause, against the use of the double-rope system. If not, it seemed to meet the difficulties for deep-winding by the additional safeguard in case of an accident. Some of the members, no doubt, would remember that he (Mr. Woodworth) read a paper some years ago on the way to avoid those practical difficulties which prevented the use of the simple Kœpe system in probably the majority of cases in this district. But he proposed the ordinary grooved ring for the balance-rope in combination with the regular drum, with fast-ropes, and by keeping the turn-pulleys above the sump, the latter would be kept quite free for all work as in the ordinary way of winding. The system could be adapted to unequal winding or flat-rope drums with every facility for balancing the ropes, etc., by the use of two ropes, one light rope for the top

side and a heavier balance-rope for the shaft, and if the upcast shaft was in line and clear, the whole of the balance-gear might be run in it instead of in the winding-shaft. There seemed to be a tendency on the part of Continental engineers to revert to the flat-rope system for very deep mines, making the ropes of aloe-fibre and of regular tapering section; but he trusted that they (in Staffordshire) would be able to meet their wants with round ropes of steel wire, either in parallel or tapering sections. Although it added greatly to the cost and difficulty of dealing with the extra depths, he had no doubt that the problem of working and winding the coals would be solved in a fairly satisfactory manner by mining-engineers.

Mr. A. M. HENSHAW said he did not think that there were many mechanical difficulties that could not be overcome. In discussing mining conducted at considerable depths and producing minerals that were sold in competition with minerals wrought from shallow depths, they should consider their commercial value. He thought that the possible difficulties arising from the temperature at greater depths had been overrated. He had worked coal at a depth of 3,000 feet from a seam 2 feet thick, and the colliers worked for 10 hours, apparently in comfort, and they got an output of coal showing that they could do a fair day's work. In their own district, the atmospheric conditions due to the depth were modified by the air-current. At a depth of 1,200 feet, the average temperature had been 65° to 67° Fahr., at a distance of 1¼ miles from the downcast shaft. The liability to gob-fires was a very serious one, and he thought that it would be one of the greatest difficulties to be overcome in mining coal at great depths. He thought that the crushing of coal worked at a depth of 3,000 feet would be a serious matter. A seam 4 feet thick, when worked at a depth of 1,500 feet, gave 55 to 60 per cent. of round coal; but at the same colliery at a depth of 3,000 feet, the percentage of round coal had decreased to 30 per cent. At great depths the crushing of roof in extensive workings would have serious effects on the produce of round coal.

Mr. E. B. WAIN said he was surprised that the balance-rope had not been adopted more generally at shallow pits. Many years ago he introduced a balance-rope, without a tail wheel, it worked successfully and saved 25 per cent. of the fuel-consumption,

and was working in the same way to-day. He did not know whether similar results could be obtained at deeper pits winding from over 1,200 feet unless with ropes specially constructed. A locked-coil rope would make a useful balance-rope for depths of 1,500 to 2,000 feet. The balance-wheel at the pit-bottom added to the already heavy load. An important factor in deep winding was the strength of the rope; but possibly they might adopt two-stage winding from mines at great depths. He believed that in a recent deep sinking in Lancashire, boilers had been fixed underground, and no doubt there was economy in generating steam as near as possible to the point where the fuel was produced, although perhaps the circumstances of many mines prevented any general application of this principle. He desired to emphasise Mr. Mitcheson's remark that the theoretically perfect machine in colliery-operations was not necessarily the best, from a practical point of view. He was working coal 8 feet thick at a depth of 2,100 feet, and he was not prepared to agree with Mr. Henshaw that at that depth the coals were more friable and produced a larger proportion of slack. The Eight-feet coal-seam was stronger at that depth, and produced a higher yield of round than at a depth of 1,650 feet, while the roof-strata were stronger.

Mr. Henshaw said that other circumstances might cause the improvement.

The President proposed a vote of thanks to Mr. Turner for his valuable paper.

Mr. J. C. Cadman seconded the resolution, which was agreed to.

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## DISCUSSION OF MR. A. T. THOMSON'S PAPER ON "UNDERGROUND ELECTRIC HAULAGE AT MANVERS MAIN COLLIERIES."*

Mr. E. B. Wain said that in many cases the best means of supporting electric cables in shafts and roadways was to fasten them in the same way as cables had been fastened for a long time in house and general electricity lighting work, except that a stronger casing was required in the mine. If the grooves of the casing in the shaft were made an exact fit to receive the cables, and the cables

* *Trans. Inst. M.E.*, 1900, vol. xx., page 29.

were pressed well home, the cable would not break. In underground roadways, the casing should be raised from the floor so as to keep it out of any water. If there was no water, the casing should be buried in a few inches of slack or anything that would protect it from being injured by heavy pieces of stone falling upon it.

Mr. G. A. MITCHESON observed that something could be said against Mr. Wain's method of encasing the cable. One objection to the use of casing was the possibility of fire. In the case of an installation of 150 horsepower, the cable became heated and fired the wooden casing. Another objection was the insertion of heavy timber in the shaft, because heavy cables would require strong casing which must be secured by proper timber. He had occasion to carry two cables, 2 inches in diameter, down a shaft nearly 2,700 feet deep. He started with the idea of placing them in steel tubes; he next considered the use of wooden casing, but that would be heavy and expensive; and ultimately he adopted an armoured cable, suspended at intervals in the shaft. The cable was inserted in lengths, coupled by junction-boxes, so that if anything happened to one length of cable it could be taken out and repaired. There was no objection to encasing the cable in the mine if it was dry, but it was objectionable in the presence of water. He preferred to have the cable in sight and to divide it into sections, but this method of suspending a cable had been adversely criticized. It was argued that however good the insulation of the cable might be, if there was moisture in the shaft, the insulation would eventually be destroyed, if the cable was held by glands.

Mr. A. M. HENSHAW approved of Mr. Wain's suggestion that the cables should be placed in wooden casing, screwed up and fastened securely, with occasional junction-boxes for testing purposes.

Mr. E. B. WAIN said that, in a wet shaft, strong timber casing, creosoted or pickled in a moisture-resisting composition, answered well. He did not think that there was any point where he could trace of leakage, except in an old armoured cable, hanging loose in the shaft. He made elaborate arrangements for putting the cable into tubes, but he reverted to the old-fashioned system of using wooden casing.

# MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT MONCKTON MAIN COLLIERY, MARCH 1ST, 1901.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

## DEATH OF HER MAJESTY QUEEN VICTORIA.

The PRESIDENT, referring to the loss of their great and good Queen, said that it was a matter of duty to pass a resolution, which, as Yorkshiremen, famous for their loyalty, was due from them. Revered and loved as the Queen was by all, to an extent that possibly was not realized until they lost her, now they were proud of her greatness and goodness, and for all time her memory would be held in veneration, wherever the English language was spoken. He moved that the following resolution should be forwarded to His Gracious Majesty the King:—

That the Members of the Midland Institute of Mining, Civil and Mechanical Engineers humbly desire to express their profound and lasting sorrow at the death of their beloved Queen, the most sincerely respected and beloved Monarch in the world, whose memory will long live in the hearts of Her People. And the Members further wish to declare their unabated and devoted attachment to the Throne and their true allegiance to His Majesty, King Edward VII., whom God preserve.

The resolution was adopted in silence, all standing.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated: —

MEMBERS —

Mr. WILLIAM ARMITAGE, Colliery Manager, Fieldhouse Colliery, Huddersfield.
Mr. ERNEST D. BLACK, Colliery Manager, Micklefield Colliery, Leeds.
Mr. SQUIRE ROBERT CHADWICK, Colliery Manager, Robin Hood Collieries, Wakefield.
Mr. KIYOTOUGU YONEKRA, Mining Engineer, Hokkaido Colliery and Railway Company, Tokio, Japan.

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Mr. CHARLES CHETWYND ELLISON read the following paper on "The Simon-Carvès Bye-Product Plant at Monckton Main Colliery": —

# THE SIMON-CARVÈS BYE-PRODUCT PLANT AT MONCKTON MAIN COLLIERY.

By CHARLES CHETWYND ELLISON.

The object of this paper is chiefly to describe the working of an electrically driven coal-compressing machine, by which the retort coke-ovens at Monckton Main colliery are loaded and discharged.* As this is the only machine of its kind in use in this country, the writer ventures to think that the subject will be of interest to the members, and to those who are connected with the coal- and iron-trades. So many excellent papers containing useful and valuable information about bye-product coke-ovens having been recently contributed by various authors, and printed in the *Transactions*, it is not proposed again to go over this ground, but it is difficult to avoid a certain amount of recapitulation in order to make the paper comprehensive.

It is almost impossible, when writing about bye-product coke-ovens, not to refer to the prejudice which has existed in this country and in America against the system of retort coke-ovens, but it has now been all but entirely overcome. In the United States, retort coke-ovens are being rapidly adopted, for carbonizing coal which will not coke in beehive coke-ovens, and are also superseding the latter type of oven. In this country, the output of bye-product or retort-oven coke steadily increases. Englishmen are very slow to adopt innovations, perhaps, because they are afraid of making mistakes and losing money, and possibly from a lack of scientific training. But it is through experiments and mistakes that the path of progress has always lain, and unless Englishmen are prepared to risk something, they will be left behind in the industrial race.

Bye-product coke-ovens have now been in use in England for many years, but unfortunately some time ago, several eminent mining-engineers, who were considered authorities on the manufacture of coke, stated that this class of oven was unnecessary

* *Trans. Inst. M.E.*, 1899, vol. xviii., page 561.

for English coals, and that the coke was unsuitable for metallurgical purposes. It is interesting, however, to follow in the *Transactions* of various scientific societies the remarks which have been made during discussions on the subject from time to time. It would almost seem as if some engineers were so short-sighted as to think that we can learn nothing from our Continental neighbours that will tend to improve our methods and machinery; but this, perhaps, applies only to those who remain at home, and never take the trouble to study a subject. It is instructive to hear the remarks of an English engineer after his first visit to modern German collieries; every one who takes any interest in his work ought to visit them. Indeed, if the young mining-engineers of this country would take their holiday in the coal-fields of Belgium, France or Germany, they would not only find it a most pleasant and instructive trip, but it would certainly materially assist in enlarging their ideas and help them in the study of their profession.

German engineers were at first comparatively slow in erecting bye-product coke-ovens, but as soon as they discovered the immense amount of profit to be derived from them, their number increased very rapidly, and at the present time the beehive coke-oven in Germany is shown to the visitor as a relic of the past.

There is much to be learnt in regard to the working of a battery of bye-product coke-ovens; there is, perhaps, no subject of greater interest in connection with a colliery; and since the erection of several plants in this district, most of the members have had an opportunity of inspecting one of them and are therefor to some extent acquainted with the process.

It is not proposed to deal fully with the manufacture of bye-products, but more especially with the entire process of the manufacture of coke, showing the improvements made in its quality and hardness by adopting the compressing machine. It is intended also, if possible, to a certain extent to answer the question, which a shrewd business man would ask, when considering the advisability of adopting such a system, "What advantage am I going to obtain, as compared with my old system of making coke?" This paper will enable members to form an opinion concerning the practical value of the plant, and if there is any further information which can afterwards be supplied, the writer will be very pleased to do so.

*Screening-plant.*—The screens from which the coal is supplied to these ovens are situated in a direct line, about 420 feet from the hopper in which the coal is stored. Previously, this coal was taken to the old ovens in railway-waggons, but if this means had been adopted for the new ovens, it would have meant that the coal would have been shunted about 1,800 feet, as there are no less than eight sidings, one set of screens, and two batteries of beehive coke-ovens between the screens and the hopper. In order to pass over or under these various obstacles several schemes were considered, as follows:—(1) To elevate the coal into a small hopper on to a gangway, to run a level gangway to the bottom of a big hopper, and then to elevate the coal on to a creeper, which would fill the various compartments of the large hopper. (2) To elevate the coal into a small hopper, and to convey it direct into a large hopper by means of a creeper rising at an angle of 1 in 8. (3) To convey the coal in corves, by means of an underground subway, and then to tip it into the boot of an elevator, which would convey it into the hopper. (4) To elevate the coal into a small hopper, and to take it thence direct into a larger hopper by means of an aerial rope-way.

The second scheme would at first sight appear, perhaps, the simplest, but the cost was found to be very heavy. The supports to carry the creeper would have been costly, although the distance is only 420 feet. The creeper, owing to its great weight, would have required a large amount of power to drive it, even when not conveying any coal, and the wear-and-tear of such a creeper is very costly—more especially when conveying coal moistened with bad water. It was therefore decided to adopt the fourth scheme as being the cheapest in first cost, wear-and-tear and labour, and requiring less motive power. Although aerial rope-ways are much used abroad in place of tramways, few, if any are in use for so short a distance, and this rope-way really takes the place of a creeper. It works satisfactorily, and the writer believes that it will shortly become a very common means of transit at collieries, when mining-engineers appreciate its simplicity and usefulness. The arrangements, although simple, are ingenious, and worthy of careful inspection.

The fine coal passes through a wire screen with a ⅝ inch mesh, and contains all the pea-nuts, the quality of the coke being considerably better than if it was made only from fine smudge.

The coal is carried by a creeper a distance of 68 feet on the level, and it then rises 1 in 3 for a further distance of 49 feet. The coal here falls into a Carr disintegrator, which is capable of treating 40 tons per hour. After passing through the Carr disintegrator, the coal drops into the boot of an elevator, which lifts it 58 feet, and delivers it into a small hopper (Fig. 2, Plate III.). It will, no doubt, be of interest to refer to a difficulty which was encountered here. The slack is not washed, and it is damped in order to make it into a cake. An Archimedian screw, working a barrel 30 inches in diameter, was fixed under the disintegrator; and water was admitted into this barrel, with the view of mixing it with the fine coal. After numerous trials, it was found impossible to make the smudge leave the worm, which became clogged up, and the screw had to be removed.

*Aerial Rope-way.*—The aerial rope-way is working most satisfactorily and economically (Fig. 1, Plate III.). The empty buckets are automatically detached from the haulage-rope, then taken a short distance by hand, and filled at the shoot, A, and at the same time water is sprayed upon them (Fig. 2). This not only damps the coal, but prevents it from blowing away in transit. If too much water be put upon the coal, it sticks to the buckets, and when tipped they do not empty completely. When the bucket is full, it is pushed along the rail, and is attached by means of a clip to the ½ inch haulage-rope. The rail slopes down at B, so that the tub may be attached to the haulage-rope, and its weight causes the clip to grip tightly the haulage-rope. The whole of the machinery, consisting of a creeper, disintegrator, elevator, and aerial rope-way, is driven by a horizontal engine, with 2 cylinders, each 16 inches in diameter, and having a stroke of 24 inches.

The bucket, on leaving the rail at the loading-station, runs on to a round locked-coil carrying-rope, $1\frac{1}{16}$ inches in diameter; and from the point of support to the hopper, D, a distance of 300 feet, there is one support, placed at a point 120 feet distant from the loading-station. The average gradient between the loading-station and the hopper, D, is 1 in 8. The buckets hold 8 hundredweights of coal, travel at the rate of 100 feet per minute, are spaced upon the rope about 90 feet apart, and at this speed 240 tons can be conveyed per day of 10 hours, but

surplus power is provided for conveying a considerably larger quantity.

The labour at the loading-station includes 1 engineman, who attends to the engine, creeper, crusher and elevator; and 1 man and 1 lad, who fill the buckets of the aerial rope-way. The cost of labour for 240 tons per day is 0·8d. per ton.

The buckets, on reaching the hopper, D, run on to a rail, C, similar to that of the loading-station. The haulage-rope is not unclipped from the tub when passing round the return-wheel, which is of such a section as to allow of the haulage-clip passing round it. The buckets, therefore, never leave the haulage-rope, and can be emptied into any part of the hopper, by setting an arm, which knocks off a catch on the buckets (Figs. 3 and 4, Plate III.). As soon as this is released, the bucket is so balanced that it turns over, empties itself, and returns on the empty-tubs carrying-rope, ($\frac{15}{16}$ inch in diameter) to the loading-station. The top of the hopper is covered with an iron-grating, so that only coal can fall through. Watering arrangements are provided at the top of the hopper to damp the coal as it falls in, but it is not always used. At the same time the water is always ready in case of fire. The man on the top looks after the filling of the hopper and the machinery. He has actually very little to do, but sometimes it is necessary for him to go into the hopper and shovel the coal to the spouts.

*Coal-storage Hopper.*—The hopper, D, is built of wood and supported on brick pillars; it is 22 feet high, and should contain, when full, about 660 tons of coal. The sides of the hopper are bolted together by tie-rods, and the hopper is bolted to the brick-pillars upon which it stands, so as to prevent it from being blown over in a gale of wind (as it stands in a most exposed position), and also to enable it to resist the pull or strain which is placed upon it by the aerial rope-way (Figs. 3 and 4, Plate III.). The hopper has a corrugated iron roof. It is lighted by electricity, and portable electric lamps are used when workmen have to go into the hopper. Iron ladders are fixed inside the hopper, and chains are suspended in various parts to ensure the safety of the men, when working in the hopper. At first, an attempt was made to do without "hoppering" the bottom of the storage-box in order that it might hold more coal, as it was thought that the

coal would "hopper" itself, and so reduce the cost. But it was found most difficult to get the coal out, and it has since been "hoppered" into 5 divisions, with sides sloping at an angle of 60 degrees and covered with steel sheeting, and the smudge now comes out readily. It is a mistake not to "hopper," as the coal which is left in the corners of the storage-box becomes heated, and is a source of danger because it may take fire. It is, therefore, absolutely necessary to clean out constantly the corners of the hopper: an expensive matter, as the whole of that part of the hopper must be emptied for the purpose.

In the bottom of the hopper are three large holes fitted with slides, worked with a wheel-and-ratchet, and from these holes the corves which run on the top of the coke-ovens are loaded.

The corves, of 46 cubic feet capacity, are fitted with axles running in ball-bearings, and the bottom-slide, which is usually pulled out by hand, is worked by means of a wheel-and-pinion working into a rack (Figs. 5 and 6, Plate III.). This is a very convenient arrangement, and saves the workmen much trouble. The corves have pockets on the sides, through which a rod can be pushed down to make the coal run out, when it sticks. This prevents a good deal of rough usage to the sides of the corfe, and also to the tops of the coke-ovens. The familiar sight of the trammer lifting one end of the corfe from the rails and dropping it, or striking the corfe with an iron bar, and gradually destroying the sides, is never seen when this class of corfe is in use, and it consequently saves a considerable amount of wear-and-tear both to the ovens and corves.

*Coke-ovens.*—The plant consists of a battery of 35 Simon-Carvès coke-ovens and a bye-product plant for dealing with the tar, sulphate of ammonia and benzol. The ovens are of the following dimensions:—32 feet 8 inches long; 8 feet 2 inches high, to crown of arch; and $19\frac{1}{4}$ inches wide at the front end, $19\frac{11}{16}$ inches at the centre, and $20\frac{1}{16}$ inches wide at the back: the ovens are made tapering, so as to allow of the coke being more easily pushed out. The sole-flue and side-flues of the coke-ovens are filled with hot air and gas, by which means these flues are heated to a temperature varying from 1,600° to 2,200° Fahr.; and the heat is transmitted through the side-walls ($4\frac{1}{2}$ inches thick) of the ovens to the coal within them.

The gas given off from the coal passes into the ascension-pipe, through a valve, and thence descends into the hydraulic main. One of the most important points in connection with the working of the ovens is the difficulty of dealing with the valves, and when the coal is very rich in tar, it is no easy matter to keep the pipes in working order. When the coke is about to be discharged from the oven, the valve is closed, in order to shut off the oven from the exhausters. Many types of valves have been tried, but few of them work successfully. A common form of valve (Fig. 7, Plate III.) has been used on these ovens, but owing to the expense and difficulty of cleaning out the pockets, F, it is found cheaper to fill these up with cement, to remove the whole of the valve, to replace it with a clean one, and to clean the valve when removed from the coke-oven. The tar and gas have every opportunity of filling up the pockets, as the gas passes vertically downward through them. The gas from the coke-oven is drawn through the inlet, A, and enters the gas-chamber or hydraulic main through the outlet, B: the cup, C, is then in the position shown in Fig. 7. When the oven is ready for discharging, the connection between the oven and the hydraulic main is cut off by lowering the cup, C, into the annular space, E, and covering the top of the pipe, B. The pockets, F, are used for cleaning out the tar, etc., which accumulates in the annular space, E. The water-seal is maintained by a water-supply through the pockets, F. The cleaning out of the pockets was found very expensive, and they were, therefore, closed; and when the valve is blocked with tar, etc., it is taken off and replaced by a clean one. The pipe, B, being only $6\frac{3}{4}$ inches in diameter, tends to prevent the gas from issuing from the oven: being of a smaller area than the outlet from the oven, it produces a pressure in the oven, and causes the gas to waste at the doors.

The valve, shown in Fig. 8 (Plate III.) is working satisfactorily, and is a great improvement on that shown in Fig. 7, as it is much simpler and easier to clean. The gas from the coke-oven is drawn through the inlet, A, and enters the hydraulic main through the outlet, B. The cone-shaped valve, C, is then in the position shown in Fig. 8. When the oven is ready for discharging, the connection between the oven and the hydraulic main is cut off by means of the valve, C, which is screwed upon its seat, E. The plate, F, is removed when cleaning the outlet,

B, and when not in use a plug is inserted in the hole. The advantages of this valve are as follows:—(1) It is labour-saving, as there are practically no traps for the accumulation of tar, etc., as in the first valve. (2) It has a larger area than the first valve, allowing the gas to pass away more quickly; this is essentially necessary with compressed charges of coal, as a large volume of gas is produced during the first few hours of carbonizing, and there is as a consequence practically no loss of gas through wasting at the doors. (3) As the gas comes off more quickly, the coking-time is somewhat reduced. And (4) the distance between the gas-outlet of the oven and the hydraulic main is 4 feet 1 inch, against 7 feet 6 inches with the first valve.

The gas then passes through the hydraulic main, in which it is cooled by water, and wherein it deposits some of its tar. The tar passes out of the hydraulic main into a pipe leading to the tar-tank. Water and thin tar are admitted into the hydraulic main, to assist in carrying away the tar deposited from the gas, and the thin tar prevents the accumulation of pitch, and fine coal-dust, etc., which causes the tar-pipe to become stopped, unless carefully watched. This flushing, therefore, saves a great deal of labour in cleaning the pipes. The water in the hydraulic main also prevents the hot gases from coming into contact with the tar, which would boil, and the volatile compounds would be driven off. The gas then passes through the water-condensers, where the last traces of tar are collected, and where the temperature is reduced to about 60° to 70° Fahr. The gas next passes through an exhauster, and is from this point forced through the ammonia-scrubbers, the benzol-absorbers, and then returns to the top of ovens, where it is utilized for heating the oven-flues.

The gas is taken from the gas-main on the top of the ovens through a tuyère, or gas-pipe, regulated by a valve. The gas at this point is mixed with hot air having a temperature varying from 900° to 1,000° Fahr. The temperature in the bottom-flue is about 2,200° Fahr. The state of the flue has to be continually watched, and the admission of air and gas regulated, otherwise the flue would very soon be burnt away. This inspection is made through a sight-hole, fitted with a plug. The ordinary plug consists of a piece of fire-brick, and being removed every time that the flue is examined permits of the entrance of cold air,

which reduces the temperature, and has an injurious effect on the hot bricks: it alters the natural condition of combustion in the flue. It was also practically impossible to inspect the flue through the sight-hole with the naked eye, owing to the intense white heat, and thus a slightly burnt flue might be overlooked and allowed to become much worse. The writer has introduced a simple arrangement, consisting of a hollow plug, fitted with a piece of coloured glass, through which the flues can be examined without removing the plug.

The gas passes out of the bottom-flue at the end of the oven, and ascends by a vertical flue into the top horizontal flue, where further air is admitted. It then travels through this flue to the other end of the oven, passing downward to the next flue, where air is again admitted; there is also an arrangement at this point for admitting gas, but it is not always found necessary to do so. The gas again passes the whole length of the oven through this flue, returns by the third flue, thence into the fourth or lower side-flue, and thence into the regenerators.

The approximate temperatures of the different flues are as follows:—Horizontal side-flues, top 1,650° Fahr., second 1,850° Fahr., third 1,600° Fahr., and fourth 1,700° Fahr.; and the bottom or sole-flue, 2,000° to 2,200° Fahr.

Underneath the coke-bench are five large flues or regenerators: the air enters the first flue, B, travels its whole length and returns through the third flue, D, and then enters the fifth flue, F. The temperature of the air when it reaches the fifth flue varies from 900° to 1,000° Fahr., and the air is taken from this flue to the gas-pipes of the several ovens. The two gas-flues, C and E, are heated by the waste gases, after they have heated the flues of the ovens, the gas from alternate ovens passing to the flue, E, going to No. 4, and the gas from the other ovens to the flue, C. The gas passes through these flues to the boilers, and is there used for generating steam.

*Methods of Charging the Coke-ovens.*—The ordinary process of charging retort coke-ovens is by means of corves running along the top of the ovens, the coal being dropped through three or more charging-holes (Fig. 9, Plate III.). When the coal falls into the oven, it forms three peaks which require levelling, in order that the oven may be properly filled. This work is done

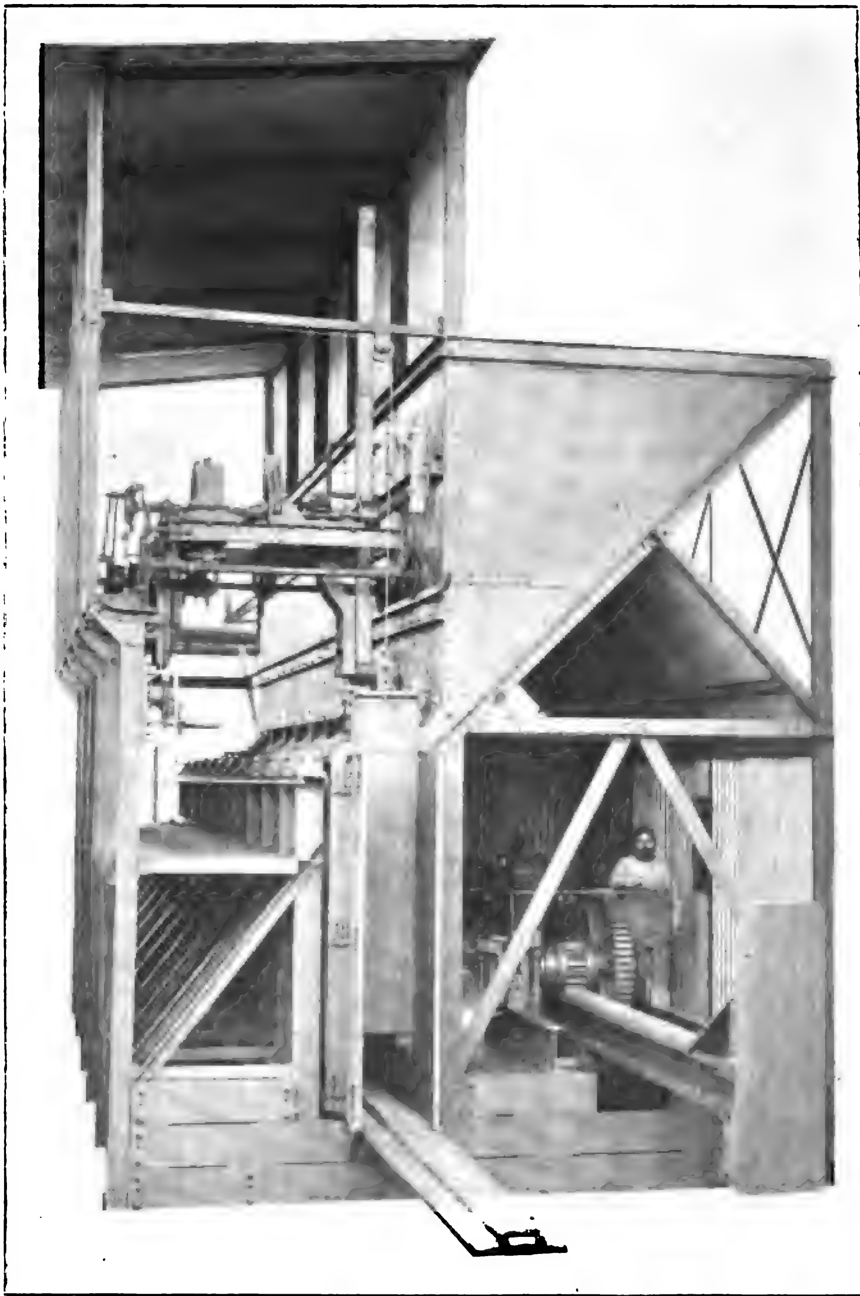


FIG. 12.—COMBINED COAL-COMPRESSING AND COKE-DISCHARGING MACHINE.

by manual labour, a rake, 20 feet long and weighing 56 pounds, being used. These rakes are made from hollow tubes, and are constantly being repaired and straightened, as they are much affected by the heat. The levelling of the coal involves very hard work, and it is difficult to ensure that it is properly done, even under the most careful supervision. When carried on at night-time, it is often carelessly done: consequently the oven is not properly filled, in some places the coal may touch the top of the oven and prevent the gas from escaping, and the gas may lie in the hollow places and become decomposed by the heat. The covers on the charging-holes of the ovens must be removed before charging, and this work is far from pleasant, as smoke and flame issue from the charging-holes. The time occupied in charging and levelling an oven is about 35 minutes.

*Coal-compressing Machine.*—The machine is very massive, and weighs, when loaded, about 75 tons (Fig. 12). It comprises a ram, H, for discharging the ovens, a small storage-hopper fixed above the ram and motor, and the box in which the coal is stamped into a cake (Fig. 10). The machine travels in front of the ovens on four heavy bull-headed rails, the motive power being electricity. The hopper, F, on the machine, is loaded by means of five creepers, E, running underneath the storage-hopper, carried on brackets fixed on the side of the storage-hopper, D, and overhanging the small hopper placed on the machine (Fig. 4, Plate III.). The creepers are driven by an engine with a single cylinder, 12 inches in diameter and 2 feet stroke, and by their use the small hopper can be filled in a very few minutes. There is a water-spray at the end of each of these creepers, by which the coal receives a further watering. Two men are required to attend to this machinery. The hopper, F, holds sufficient coal for about 1½ oven-charges. It is therefore not necessary to stop the compressing process when the machine is away from the storage-hopper, as having made one cake there is still sufficient coal in the hopper on the machine to proceed with the making of the next cake. The coal falls into the stamping-box, G, through hinged doors, which are opened and closed by hand. The box or chamber, G, in which the coal is stamped or made into a cake is slightly less than the size of the ovens so as to allow sufficient clearance: it is 32 feet 6 inches long, 7 feet 4

inches high, and 1 foot 6 inches wide. It consists of a moveable sole-plate driven from the large motor by means of rack-and-pinion gearing. The sides of the box are made of sheet-iron, and one side is hinged at the bottom, so that when the cake is completed, one side can be released and so reduce the side-friction, when the cake is being pushed into the oven. At the front end, there is a movable door, which is raised and lowered by means of a small winch. At the back end, the door is held in position by two screws, which are attached to a bracket bolted to the sole-plate; and the door can be moved backwards and forwards by means of these screws, which are 8 feet 2 inches long.

Commencing with an empty box, a layer about 14 inches deep of coal is admitted, and stamping is commenced as soon as there is sufficient coal in any one part of the box. The bottom layer must be most carefully stamped, as it has to bear more weight than any other layer; consequently the higher the layer, the less stamping it requires, or the thicker it may be made. It is absolutely necessary that the coal should be thoroughly well moistened, in order that the cake may be sufficiently strong to prevent it from breaking when the oven is being charged. The coal can be watered by jets, fed from a cistern on the machine. As the coal is admitted into the box it is levelled by rakes, when necessary. The stamper consists of an iron head, or hammer, 17 inches long, 11 inches wide, and its weight is 196 pounds. It is attached to a rod or shaft of hard wood, 12 feet 9 inches long, of square section and it can be relined when worn. The hammer is lifted about 18 inches, by means of friction-wheels, actuated by springs and a cam-motion, and is then released. The hammer and the machinery which drives the hammer is carried on rails, the speed of which can be regulated. It is driven by an electric motor of 2 horsepower running at about 1,500 revolutions per minute. The time taken to travel from one end of the box to the other is 1 minute 25 seconds, the hammer making 38 strokes per minute, and after every stroke the machine is moved along the rails for about 7 inches. It is usual to let the stamper travel over a layer of coal at least twice, before admitting more coal; and at the end nearest the oven special care has to be taken to stamp the cake thoroughly, else it will break off, before it can be placed in the oven.

Two wooden hand-stampers are provided in order that a few extra blows may be given by hand, at the ends of the box. The front end of the cake is tapered down as shown in Fig. 10 (Plate III.), because, if the cake were made of full size, the top part would break off when going into the coke-oven. The writer has tried various methods of preventing this breakage, such as inserting layers of straw, and thin laths of wood. The latter plan acts well, it does not cost much, and more coal can be put into the oven; and the coal reaching nearly to the top of the door protects it from the heat, as the doors are more liable to damage when a space is left between the coal and the door.

Two men are required to work the machine, and one of them also works the ram. The cake having been completed to within a few inches of the top of the box, the machine is placed in position for loading the oven. The time occupied in making the cake is about 40 minutes. The weight of a cake is approximately 11 tons, of which nearly 18 per cent. is moisture. Owing to the difficulty of moistening the coal thoroughly and evenly, it is necessary to use more water than is really necessary to make the coal into a firm cake. It is very difficult to mix coal-dust and water; some portions of coal throw off the water and refuse to mix with it in a most extraordinary manner. This difficulty and trouble does not occur when the coal is washed, much less water is then required, and the yield of bye-products and coke is much greater. The excessive quantity of water also requires more heat to drive it out of the coal.

The machine is propelled along rails placed parallel to the front of the coke-ovens by means of an electric motor of 25 horsepower working at 210 volts, and about 35 to 50 ampères. It takes its current from overhead wires, and can travel at the rate of about 80 feet per minute. The motor is geared, and can be thrown in and out of gear by means of clutches. This motor also works the ram and sole-plate of the coal-box.

*Discharging the Coke.*—The door of the coke-oven which is to be discharged, having been opened, the ram-head is placed opposite to it. The ram consists of a heavy head faced with sheet-iron, having two vertical rollers on either side and an horizontal roller to prevent it from damaging the oven. At the bottom of the ram is fixed a hinged scraper, which, when the ram

is being withdrawn, scrapes the dirt and graphite off the sole of the oven. This improvement was introduced by the writer after having seen the machine at work in Germany, where the machine has to be removed and two men, one at each end of the oven, scrape the sides and floor, as best they can, with long scrapers. The German coal produces much graphite. No difficulty has arisen in using the scraper, which has not damaged the sides or floor of the ovens. This scraping is of course a very important point, as the accurate fit of the sole-plates of the box makes it absolutely necessary that the oven should be quite clean, and the scraper consequently saves both time and labour.

*Watering and Cooling the Coke.*—After the coke has been pushed on to the bench, it is quenched or cooled from two hoses, with water supplied from a special pump, at a pressure of 50 pounds to the square inch. The coke comes out of the oven like a solid wall, and will stand up while being watered; and, when the external surface is no longer red, it is pushed over and dragged out by 5 or 6 men. It is most important that the coke should be spread out as much as possible, so that the air can get at it and cool it. It is then again watered slightly, and this is the time when careless watering spoils the appearance of the coke.

The writer has tried many methods of cooling the coke, and finds that watering it when standing up, is the best way to produce a good appearance. The water will not percolate as far as the centre of the charge of coke; therefore the heat from the centre drives off any excess of moisture on the outside of the wall of coke. So, if the interior be carefully watered when spread out on the bench, there is no reason why the coke should not look nearly as well as any coke made in beehive coke-ovens. The higher the water-pressure the better, as it is possible with a very high pressure to force the water almost into the centre of the charge.

The quenching or cooling of the coke is a subject which is worthy of careful study. Several arrangements have been tried for improving the appearance of the coke, and reducing the percentage of sulphur, but the writer has no knowledge of their practical utility. However, he believes that if the red-hot coke were pushed into a suitable box or chamber, in which it could be quenched, and if this box were then run on rails to a screen,

where the ram would push the coke out of the box on to the screen, the large coke passing over the screen into the waggons, the appearance of the coke might be improved and a saving of labour effected. It seems impossible to reduce the labour required for dealing with the coke after it is pushed out of the oven, unless it be done in this manner.

The writer has considered the question of using an electric crane, the coke being filled by hand into a bucket which would be tipped when suspended over the wagon. He found that this system would not reduce the cost of labour, as the number of men now employed would not be decreased. The idea of picking up the coke by means of a grab or claws has also been considered, but it is not thought desirable.

*Charging the Coke-oven.*—As soon as the coke-oven is ready to receive the charge, the cake-chamber is put in position. Great care has to be taken to set it exactly opposite the oven, and the foreman should always superintend this work. As soon as the cake-chamber is in position, the hinged side of the box is released and drawn back about 1 inch, and fixed in this position. The front door of the chamber being raised, the cake is now resting on the sole-plate, and entirely unsupported at the sides, and the rack of the sole-plate having been thrown into gear, it is started very slowly, and as soon as the front end of the cake is well inside the oven the speed is increased, and the cake rapidly placed in the oven. The back door of the chamber, which, as previously explained, is attached to the sole-plate, is withdrawn by means of two screws worked by a worm-and-wheel, and when it is far enough back, the oven-door is closed and barred, the door closing over the top of the sole-plate. The time taken is about 2 minutes 12 seconds. The motor is now reversed, and the sole-plate withdrawn from the oven into its original position in the box or compressing-chamber. The oven being very hot, the sole-plate, during the process of loading, takes up a considerable amount of heat and it is advisable to cool it down with water directly it is withdrawn from the oven, as the heat from the sole-plate tends to dry the first layer of coal of the next cake, causing it to give way and fall when being placed in the oven. The hinged side of the box and the end doors are then put back into position, and stamping is recommenced at once.

The folding-doors on the front of the machine are intended to prevent the cake from falling, when being placed in the oven; but owing to the difficulty of fixing them in consequence of the gas-pipes being in the way, they are not used, and there is really no necessity to use them when the cake is properly made.

A steam-hoist is fixed near the large hopper for elevating the corves to the top of the box, F, on the ram, in order to load it. This hoist will be used in the case of a breakdown to the creepers, or for testing the weight of coal charged into the oven (Fig. 4, Plate III.). This hoist is also capable of raising the trams from the bottom-level, and any portions of the cake which may break off, or any coal lying in front of the ovens, can be filled into corves and put into the hopper on the machine, so as to avoid any waste of coal. Corves are also used for removing the daub which comes off the oven-doors when they are being opened.

*Conclusions.*—The advantages accompanying the use of the machine are, among others: (1) It is a labour-saving appliance; (2) it produces an improved quality of coke; (3) it gives an increased output of coke per oven; (4) it gives an increased yield of bye-products; (5) its cleanliness; (6) reduced wear-and-tear of the ovens, owing to there being no tramming by which the ovens are often much shaken; and (7) facility of closing oven-doors on the bench side.

(1) The saving of labour arises under two heads: (*a*) The machine, being made to travel to the storage-hopper, entirely dispenses with any tramming. This arrangement is the only one, to the knowledge of the writer, where the small hopper on the machine is loaded in any other way than by means of corves, which have to be trammed by hand to the machine. This arrangement saves at least 1 man per shift. (*b*) The arduous work of levelling is entirely abolished, saving 2 men per shift, and this being hard work, high wages are paid for it. Against these savings must be placed 1 extra man per shift employed in working the stamper, but his wage is more than compensated for by the increased quantity of coal which can be placed in the ovens when charged by this machine.

(2) The improved quality of the coke is by far the most important point to be considered. An experienced person can

tell from the coke (when the coal is loaded in the ordinary way) from which part of the oven it has come. In all retort coke-ovens, the coke at the bottom of the oven is by far the best, because the lowest side-flues are the hottest, heat is also transmitted from the sole of the oven, and, moreover, the weight of coal above this bottom-layer presses it down. Consequently good coke is nearly always made at the bottom of an oven, even if the top or greater bulk of the charge be of an inferior or spongy nature. From this point upwards the gas must bubble through the centre of the charge, and causes a division between the two sides: this line varies according to the difference in temperature of the side-walls. In some cases, the separation is nearer one side than the other, and the coke becomes less dense according to its position.

When the cake of coal is placed in the oven, the gas seems able to pass more regularly up the sides, and the top being level it has free access to the ascension-pipe, which leads to the exhauster. The charge being more or less of a solid block, the gas does not seem to be able to bubble through the centre, and frequently the coke comes out in pieces of the full width of the oven. The coke from a properly burnt charge, loaded in this way, is practically all good strong coke and can be sent out as of first quality. It is of immensely improved appearance, and of great mechanical strength. When the tops of the ovens contain spongy pieces of coke such as are not fit for blast-furnace coke, this increases the labour of dealing with it; and in bad weather and at night time it is difficult for the men to keep the bad coke out of the wagons. Moreover, the more of these pieces that there are, the more breeze-coke and dust will be made when loading into the wagons or falling on to the bench. At many coke-oven plants, additional machinery is provided for breaking up the spongy pieces of coke and riddling them; and it is impossible to do otherwise where the percentage of breeze is large. A considerable reduction can be made in the quantity of breeze and spongy coke, if the temperature of the ovens are high and properly worked, bearing in mind that great differences exists between various coals.

(3) The difference between a full hand-charge, and a full machine-charge is an increase of about 15 per cent. of coke per oven; and if the moisture in the coal were less, which it would

be if the water could be properly mixed with the coal, it would then be slightly greater (Figs. 10 and 11, Plate III.). This increase implies that, if the ovens are burnt off in the same number of hours, the plant is capable of producing 15 per cent. more coke than it was originally erected to do. If the moisture in the coal be not excessive, and if the temperatures be high, there is no reason why the coke should not be burnt off in the same number of hours as when hand-charged, as the gas is given off more regularly, and there is plenty of gas to heat the side-flues.

(4) As there is more coal carbonized, consequently more gas is given off, from which the bye-products can be extracted. When loading the oven by hand, the time required is about 35 minutes, and, deducting from this the time taken by the machine there remains over 32 minutes (or about 1 per cent. of time required to carbonize the coal) during which the charging-holes and doors of the oven are open and the gas given off is being wasted. Until these orifices are hermetically sealed, the gas cannot be drawn off by the exhauster, and a considerable amount of gas is wasted.

(5) As there is no running of corves on the top of the ovens, there is no coal left lying about, and during the process of charging very little smoke and gas is given off.

(6) The ovens are not shaken by the running of the corves on the top of them; and this is of importance, as the slightest vibration will cause leakage in the side-walls of bye-product ovens. The placing of the cake in the oven does not cause any damage to the floor or sides.

(7) When the oven is loaded by means of the compressing machine, the coke, when pushed out of the oven, stands up in a solid wall, and does not break up and fall round the oven-door, and prevent it from being shut until the coke has been cleared away by hand. The cooling of the hot coke near the door is liable to cause damage to the oven and the door. The difficulty of shutting the door is of course entirely avoided when vertical doors are used, and the writer strongly advises their adoption, as they are far superior to hinged doors.

It is essential that the oven-walls should be straight, otherwise it is impossible to place the cake in the oven, or to push it out; and if the width becomes much contracted, the ram-head will not pass through the oven.

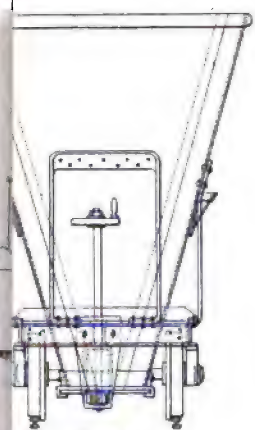


Fig. 5.

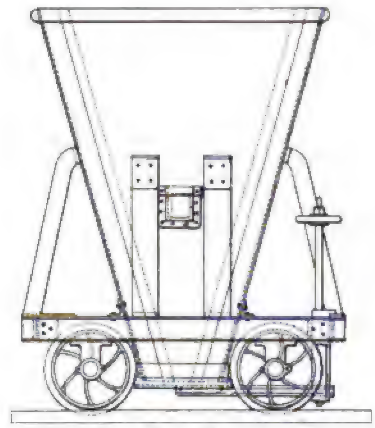
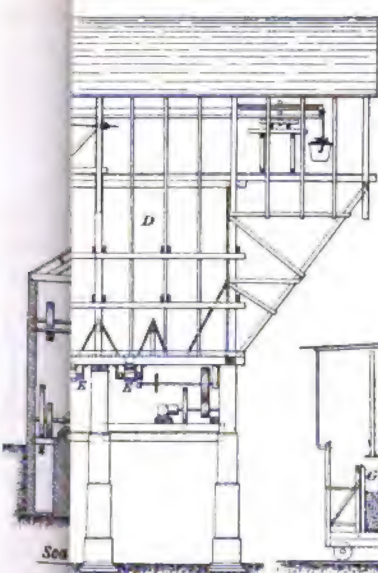


Fig. 6.

*Scale, 3 Feet to 1 Inch.*



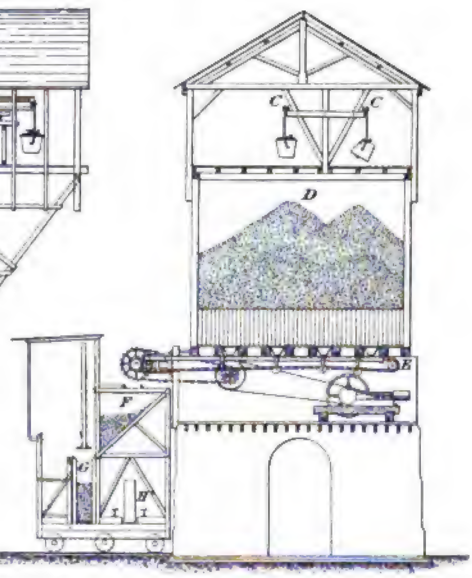




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Fig. 4.—Cross Section of Coal-storage Hopper.

*Scale, 24 Feet to 1 Inch.*

Fig. 10.—Longitudinal Section of Coke in an Oven Charged by Machine.

Fig. 11.—Longitudinal Section of Coke in an Oven Charged by Hand.

*Scale, 24 Feet to 1 Inch.*

The coal-compressing machine at the Monckton Main collieries is the largest which has ever been built, the ovens also being larger than any in use in Germany, where the machine is now being adopted. There are several classes of machines: in some the stamping-arrangement is stationary, the loaded box being taken to the oven, and after being emptied it is brought back again for refilling.

Although improvements might be made in this machine, with the exception of a few weak places, it has given every satisfaction; and other engineers are adopting coal-compressing machines for coking-plants in this country.

The ovens work continuously, so that there is practically no time for repairs to and renewals of the machine, and the writer has suggested that, although more costly, a machine fitted with two boxes and two separate stamping-arrangements would be an improvement. Several machines are now being constructed to stamp with a wider and heavier head, and at a greater speed, so that the cake may be made in a shorter time, and the machine consequently able to do more work. No doubt this may be an improvement in some ways, but there may be a difficulty in admitting the coal into the chamber fast enough for the stamper, and the difficulty of overcoming repairs and breakdowns would still exist.

In case of a breakdown of the machine, the ovens can, of course, be loaded in the ordinary way; but this should always be avoided as much as possible, owing to the inferior coke which is then made.

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Mr. C. E. Rhodes said that he had great pleasure in proposing a vote of thanks to Mr. Ellison for the admirable paper which he had read on this very important subject. He had no doubt that the Simon-Carvès system of coking was making rapid strides in this country, and as time went on, the beehive coke-oven would become a thing of the past. There was much to be learnt in connection with the working of bye-product ovens, and the old saying that "an ounce of practice was worth a ton of theory" was a very apposite saying in connection with them.

Mr. W. H. CHAMBERS seconded the vote of thanks to Mr. Ellison for his paper.

The resolution was agreed to.

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The members then inspected the surface-works of Monckton Main colliery, the aerial ropeway, coal-compressing and stamping machinery, etc., after which luncheon was kindly provided for the members, about 100 of whom attended, by the Monckton Main Colliery Company.

The PRESIDENT (Mr. John Gerrard) moved a vote of thanks to the Monckton Main Colliery Company and to Mr. Ellison, for their hospitality and their kindness in allowing the members the opportunity of visiting the collieries and works.

Mr. JOHN NEVIN, in seconding the resolution, said that the coking processes were most interesting, and the method of charging the coke-ovens was entirely new.

The motion was agreed to.

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# MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE ROYAL VICTORIA STATION HOTEL, SHEFFIELD,
MARCH 30TH, 1901.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. EDWARD JAMES GOMERSALL, Mining Lecturer, Leeds Technical School, St. Andrew Terrace, Batley.

Mr. EDMUND LEDOUX, Engineer, Simon-Carvès Company, Limited, 20 Mount Street, Manchester.

Mr. M. H. HABERSHON read the following paper on "A Joint Colliery Rescue-station":—

# A JOINT COLLIERY RESCUE-STATION.

By M. H. HABERSHON.

In bringing the subject of colliery rescue-stations under the notice of the Institute the writer would refer to Mr. W. E. Garforth's "Suggested Rules for the Recovery of Coal-mines after Explosions,"* in which, in a footnote, he says:—"Probably, in the near future, groups of collieries will establish and support central-district depôts for the storing of 'colliery-accident apparatus' and the training of men to explain and use them."† From the various discussions on this paper which have taken place at meetings of the federated institutes it seems to be generally admitted by those who have had experience in recovery-work that concerted arrangements are extremely desirable. In *Explosions in Coal-mines,* written by Messrs. J. B. & W. N. Atkinson, in 1886, a suggestion of a similar nature was made.‡

It will be convenient to quote one or two remarks which have been made in the discussions above-mentioned and elsewhere. Mr. J. R. R. Wilson said that "every one who had taken part in exploration-work could not but be impressed with the necessity for having safety-appliances, such as the pneumatophore and compressed-oxygen cylinders, immediately available for use."§ Mr. Maurice Deacon, failing to get other colliery-owners to join, had adopted such an apparatus himself.|| Mr. J. B. Smith remarked that unless such apparatus was kept clean and used periodically, it was only a trap; and stated that a Fleuss apparatus, kept for some years, was found to be of no further use.** Mr. Franz Büttgenbach, referring to the explosion at Carolinenglück colliery, said that "it will be useful to have oxygen at one's disposal in all coal-mines, to be used in cases of suffocation."†† Mr. J. L.

* *Trans. Inst. M.E.*, 1897, vol. xiv., page 495. † *Ibid.*, page 502.

‡ Page 129. § *Trans. Inst. M.E.*, 1898, vol. xv., page 251.

|| *Ibid.*, 1898, vol. xvi., page 116. ** *Ibid.*, page 117.

†† *Revue Universelle des Mines*, 1898, vol. xliv., page 262; and *Trans. Inst. M.E.*, vol. xvi., page 580.

Routledge said that after the explosion at Micklefield colliery, cylinders of compressed oxygen were obtained in the afternoon, and were the means of saving life.*

In the restoration of Karwen colliery, in 1894, Bremen respirators were used successfully; in these, air compressed to 75 pounds per square inch was reduced by regulators to 18 pounds for breathing, iron reservoirs containing air for 1½ hours' breathing were supplied, and Bristol accumulator-lamps were used, burning 6 hours. It was found, however, that 5¼ cubic feet of air were required per man per minute or 15 times as much as for ordinary breathing, a large amount of air being required for cooling and ventilating the mask, whereas 2 to 3 cubic feet of oxygen will keep a man alive for an hour while exerting himself; this volume can be compressed into a steel bottle of ½ litre, or less than a pint, the cost of the oxygen being about 6d.†

Dr. J. S. Haldane, in his report to the Home Office on *The Cause of Death in Colliery Explosions and Underground Fires*, has clearly shown that in the great majority of cases the actual cause of death is poisoning by carbon monoxide, and that, taking the average of a number of explosions, some 77 per cent. of the men, whose lives have been lost, might have escaped but for the deadly nature of the after-damp. It is thought that the majority of miners are not overtaken by after-damp until 1 or 2 hours after an explosion, and there is no doubt that men in the coal-faces, who have been out of the immediate range of explosions which have occurred in other parts of the pit, have lost their lives in attempting to get out through roadways filled with after-damp, and there have been instances of men who have lived for some hours in the faces after explosions. By the erection of sheets for the purpose of keeping back the after-damp it has been suggested that in such cases the period of possible safety might be prolonged considerably.‡ Dr. J. S. Haldane points out that after-damp may cause death either from deficiency of oxygen or from the presence of carbon monoxide, and that if the after-damp be quite free from air or oxygen it can make no difference whether carbon monoxide is present or not, since carbon monoxide has the same action as deficiency of oxygen.

* *Trans. Inst. M.E.*, vol. xv., page 251.

† *Ibid.*, 1895, vol. x., page 558.

‡ *Ibid.*, vol. viii., page 189.

The remedy for carbon-monoxide poisoning is the administration of oxygen, and Dr. J. S. Haldane has stated that "the quantity of oxygen required to get rid of enough carbon monoxide from the blood of a poisoned man to enable him to walk when breathing air would vary according to the amount of carbon monoxide absorbed. But for an average quantity, he should think about 2 feet, or say 10 minutes' breathing, would be about the right quantity. A few breaths would probably restore consciousness, but much more would be necessary to clear out the blood sufficiently to enable the man to walk."* Steel cylinders or bottles capable of holding 4 cubic feet of oxygen (compressed) can be easily carried slung over the shoulder, and will furnish enough oxygen for the restoration of two men.

The most recent form of apparatus for breathing in a noxious atmosphere by means of compressed oxygen is the pneumatophore, a short description of which by Dr. Fillunger will be found in the Transactions.† The Walcher pneumatophore has been described by Mr. Richard Cremer,‡ and a more recent type is the Neupert rescue-apparatus.§ The pneumatophore is largely used in some of the coal-mining districts of the Continent. It is reported that at one colliery in Prussia 16 lives were saved by its use.‖ The value of the pneumatophore has been for some time generally recognized in Austria. By an Imperial Regulation, dated Vienna, April 6th, 1897, it was made compulsory that stations must be provided near the travelling shaft with suitable apparatus for respiration in noxious gases and a responsible official in charge—a definite percentage of the number of persons employed being trained in the use of the apparatus.** In Saxony, new mining regulations come into force on April 1st, 1901, requiring breathing apparatus and portable electric lamps to be kept in readiness at collieries; and at the Shamrock colliery in Westphalia a very complete organization for the teaching and practice of rescue-work has been established.

In the South Yorkshire district, a number of colliery-owners have provided themselves with apparatus comprising one or two pneumatophores, but it is to be feared that their value in an

* *Trans. Inst. M.E.*, vol. xiii., page 288.

† *Ibid.*, vol. xii., page 693.

‡ *Ibid.*, vol. xiv., page 575.

§ *Ibid.*, vol. xvi., page 580.

‖ *Ibid.*, vol. xvi., page 99.

** *Ibid.*, vol. xiv., page 582.

emergency will be considerably less than it should be, because men are not being trained to use them, and in fact they are likely to become only "a trap."

Real exploration or recovery-work cannot be done with only one or two pneumatophores and without previous practice with the apparatus and proper relays of trained men, oxygen-cylinders and other necessaries. In fact, a careful consideration of the matter soon leads to the conclusion that isolated action, unless on a very complete and expensive scale, is not likely to lead to the desired results.

The Midland Institute of Mining, Civil and Mechanical Engineers, some time ago, appointed a committee to report on the general question of rescue-stations, and this committee have suggested that various collieries in the district should group themselves together for this purpose, but so far nothing further has been done.* Mr. W. E. Garforth, however, has stated that, at the West Riding collieries, experiments are to be made to ascertain how far men are able to penetrate into noxious gases, and that for this purpose he intended to use a gallery about 100 feet long, sufficiently high so that the explorers might have to ascend and descend 8 to 10 feet as would be the case with a fall of roof in a mine.†

In order that the pneumatophore may be of real use in any actual work of rescue or exploration it is essential that there must be at hand without any serious lapse of time not only a number of pneumatophores, say not less than five, all of which must be in proper working order, but also an adequate supply of compressed-oxygen cylinders and bottles of caustic soda, and a number of men experienced in the use of the apparatus; unless these are available there is great danger of the apparatus becoming only a trap, and the contemplated rescue or exploration-work ending only in failure.

It is possible in many large towns to obtain cylinders of compressed oxygen, but only in small quantities, as no stock is kept, and often notice has to be given, and sometimes several days are required. Compressed oxygen in quantities, such as would be needful for the purposes under consideration, can only be obtained from the oxygen works at Manchester or Birming-

* *Trans. Inst. M.E.*, vol. xviii., page 74.

† *Ibid.*, vol. xviii., page 483.

ham. The delay consequent on having to telegraph for and await the arrival of a supply of oxygen would probably render any proposed use of pneumatophores by a rescue-party too late to be of any use in saving life; and too late for the exploration-work which is generally of immediate importance, and which (although it has been impossible in many cases that have happened in the past, owing to the deadly nature of the after-damp) should not in any future case be considered impossible. A few trained men with pneumatophores and electric lights and a proper reserve-supply of oxygen, etc., would be able to penetrate any atmosphere, however noxious, and if they could get into the pit during the first few hours after an explosion, might obtain information which would be invaluable to those in charge, and facilitate the work of reaching any men who might be shut-off from access to the shafts, and, of course, render assistance to any men met with in proximity to the pit-bottom.

It must be remembered that although fire-damp explosions are fortunately now comparatively rare in this country, yet as Mr. W. E. Garforth has reminded us, "it is often the unexpected which happens," and that underground fires are still of too frequent occurrence.

Without referring back more than ten or a dozen years it will be sufficient to recall the disastrous underground fires which have occurred at Maurice Wood, Penicuik colliery, in 1889; Wheldale colliery in 1891; Bamfurlong colliery in 1892; Great Western colliery in 1893; and at Snaefell lead-mine in 1897. And there have been other cases in which serious loss of life has been only narrowly averted.

The possibility of fires occurring on the surface to the heapstead or buildings in close proximity to the downcast shaft, and the air-current being fouled by smoke, is a source of danger of which we are also occasionally reminded. In 1899, two cases of this kind happened. At Broomhill colliery, Northumberland, the plant around the pit-top was almost totally destroyed by fire in ½ hour. Fortunately only two men were in the pit at the time, and they were able to effect their escape by means of a day-drift. At Binchester colliery, Bishop Auckland, the heapstead took fire, and 200 men who were underground at the time were got out at the other pit. In the Ostrau-Karwin district, the Mining Police Regulations now require that in the case of pits provided with

several intake ventilating shafts, doors must be erected in all levels opening into any shaft liable to be endangered by fire, to be closed in case of a shaft-fire in order to isolate the shaft from the workings, and the provision of reserve-doors has also been recommended for all intake levels, even in cases where there is only one downcast shaft. To provide for the possibility of fires occurring in downcast shafts in some cases exhaust-injectors have been fitted, to enable the ventilation to be reversed in the shaft after the stoppage of the fan.

The comparative immunity from gob-fires which has hitherto been a feature of this district will probably become less, and with greater depths and inferior seams there will be difficulties to grapple with—one of which is likely to be an increased liability to gob-fires.*

The rapidly extending use of electricity for the transmission of motive power underground is also a matter which demands increased care, and the fact that we have in this a new possible source of danger in the event of short-circuiting, or insulation breaking down must not be overlooked. Mr. W. N. Atkinson has lately called attention to this in his presidential address to the North Staffordshire Institute of Mining and Mechanical Engineers.† The short-circuiting of an electric cable resulted in the loss of 16 lives at Hermenegilde colliery, in Austrian Silesia, on January 14th, 1896. In this case, a safety-lamp was found burning in one of the stalls near the body of an asphyxiated horse. This disaster could have been prevented, had it been possible to get at and close in good time an open air-door, inaccessible on account of the suffocating atmosphere in the heading. In December last, at a colliery near Coventry, 10 ponies were suffocated in the underground stables, owing to a fire occurring at the switchboard of an electrically-driven pump, 3,000 feet from the pit-bottom. At a West Yorkshire colliery, quite recently, a serious fire originated from an underground electric motor.

A study of the *Reports* of H.M. inspectors of mines reveals cases of suffocation by natural gases, in which sometimes even a single pneumatophore and a man experienced in its use would have been of the greatest possible value. For example, at Earnock colliery, Lanark, in 1898, a man was suffocated by fire-

* *Trans. Inst. M.E.*, vol. xviii., page 404.

† *Ibid.*, vol. xx., page 109.

damp, and 8 hours elapsed before his body could be recovered, as all who attempted the rescue were affected by the gas.

The above considerations have induced three neighbouring colliery companies in this district to take steps to provide a joint central rescue-station for their respective collieries. It has been decided to erect a building containing a room, 28 feet by 15 feet, in which a number of men can be trained in the use of the pneumatophore in a noxious atmosphere; also a store-room, overhead, for the various apparatus and stores, with an apartment for changing and a bath-room, and living accommodation for the caretaker. The building is so designed that it can either be extended or converted into cottages, if at any time it should be found desirable to discontinue the station. The building will be in telephonic communication with the various collieries and centrally situated, and also suitable for purposes of instruction in ambulance-work generally, including the administration of oxygen for restoration. The station will be in the constant charge of an attendant; and it is hoped for this purpose to secure the services of a retired soldier or pensioner who would be able to act as instructor to the members of the rescue-corps, and to keep the apparatus and stores in proper order.

After consideration of various designs, the building illustrated in Figs. 1 and 2 (Plate IV.) has been adopted. The practice-room, 28 feet by 13½ feet, will be fitted on one side with glazed windows, so that the whole of the interior can be seen from an adjoining corridor. The room will be practically air-tight, and will be arranged so that it can be heated and filled with a noxious atmosphere: an open stove being provided for this purpose. The building will be lighted by electricity, and means will be provided for charging portable electric lamps.

The station will be vested in three trustees nominated by the subscribing colliery companies. The trustees will act as a committee of management, and will have entire control of the station and the arrangements connected therewith. It is intended that the station shall contain in the first instance not less than 6 pneumatophores, each complete with all the necessary fittings, including 2 small cylinders of compressed oxygen, 1 bottle of caustic soda, and 1 knapsack, a number of portable electric lamps, not less than 8 additional oxygen-cylinders of 36 cubic inches (0·6

litre) capacity for each pneumatophore, a supply of bottles of caustic soda and other fittings and spare parts of the apparatus, goggles, pressure-gauges, thermometers, and apparatus for measuring-work.

It is desirable that the station shall eventually contain 10 pneumatophores, this number being considered the proper complement and sufficient for the equipment of two complete rescue-parties. The station will be started with a few pneumatophores, and the number gradually increased, as it will be better to train a few men efficiently than to have a large number only partially trained.

*Constitution of Rescue Corps.*

It is intended that a number of deputies and workmen shall be selected from each colliery or pit in the group—only strong, healthy, resolute and calm men who are fit for such work being chosen; and preference should be given to men who habitually breathe through the nostrils. And it is desirable, if possible, that the men chosen should be holders of first-aid certificates or medallions from the St. John Ambulance Association. These men will attend practices or drills with the apparatus at the station until they become sufficiently experienced and have obtained the necessary dexterity in the use and handling of the apparatus, when they will be enrolled as members of the corps. It is expected that about five practices will be required for this purpose. A list of the names and addresses of efficient members of the corps will be posted up at the station and supplied to each colliery. It is intended that a sufficient number of the men employed by each of the subscribing companies shall be trained so that eventually each colliery will have a rescue-party composed entirely of its own men.

In framing the following regulations and suggested rules the existing arrangements in operation at Shamrock colliery have been considered and adapted to the local conditions where thought suitable.

A rescue-party must consist of six efficient members of the corps, namely:—(*a*) One manager, under-manager, or official in charge; (*b*) one deputy (or official) capable of taking the lead; and (*c*) four other members of the corps. It is desirable that a rescue-party shall consist of not less than 5 persons when in the pit. It is also desirable that from each pit or seam a sufficient

number of men be enrolled so that in any emergency a rescue-party can be formed irrespective of any members of the corps who may be at work in the pit at the time, and so that an official or deputy who has a knowledge of the particular workings or seam can be included in the party. In the case of a colliery or pit working three seams, with separate deputies for each seam, the members should include two deputies from each seam, not employed on the same shift, and eight other men, only four of these being usually employed on the same shift.

Members of the rescue-corps will in every case have a specially distinctive "check" which will be similar at all the pits in the group, so that the manager at any pit may see at a glance what members of the corps are available at any time by simply looking at the "check-board" in the time-office on the surface.

*Training of the Rescue Corps: Proposed Rules.*

(1) It is suggested that if possible in the first instance practices should be held weekly. Afterwards it is probable that monthly practices would be sufficient.

(2) Separate practices will be allotted to the men from the various collieries.

(3) As a rule, five practices will be necessary to enable a man to become sufficiently experienced in the use of the apparatus.

(4) Four men shall practise at once. Officials or deputies shall practise with other members, as occasion arises or as convenient. In 5 weekly practices, 4 men will thus be trained, and in 25 practices, 20 men.

(5) Each member of the party must practise with the apparatus, until he can breathe for 2 hours, and at the same time perform 20,000 foot-pounds of work. This will be the standard to which members will be expected to attain after sufficient practice.

(6) Each qualified member of the corps will be expected to attend 3 practices every year at the rescue-station.

(7) Responsible managers will be expected to make themselves thoroughly acquainted with the use of the apparatus, and shall attend at least one practice annually, otherwise the full usefulness of the corps will not be attained.

(8) Before each practice, the construction and use of the apparatus must be explained by the instructor.

(9) All the pneumatophores in the station shall be used in rotation.

(10) Members must be experienced in the packing, transport and handling of the apparatus.

(11) Intimation of change of address of any member, or removal to another colliery or district, must be forwarded by the colliery-manager to the caretaker at the station, within one month.

(12) Lists of the names of members with their addresses and places of work, revised up to date, shall be kept posted at the station, and shall be supplied to each colliery-manager, every six months.

A periodical inspection of the station will be made by the committee of management, and the caretaker will be required to furnish a report every three months, giving particulars of the stores in the station, and the condition of the apparatus. The managers of the pits will be required to see that at least one-third of their members of the corps are at any time aboveground. Their attention will be specially drawn to Mr. Garforth's "Suggested Rules"* and they will be requested to provide themselves with the information which shall be included in the "Emergency Drawer," and shall see that this is available at any time on emergency.

Special regulations will be drawn up in regard to the keeping and care of the apparatus at the station. Members practising will become familiar with these, and the officials will thus be able to see that any pneumatophore which may be stored at collieries is kept in proper order, and kept supplied with the necessary allowance of oxygen and caustic soda so that it may be available if suddenly required, and not become merely a trap.

*Suggested Rules for actual Rescue Work.*

(1) Members of the rescue-corps must, on receiving intimation of the necessity, proceed at once to the place where rescue-work is required, and shall place themselves at the disposal of the manager in charge.

(2) Every member of a rescue-party, who may be requisitioned by a manager in charge, must submit to the control of the leader of the party, who must be either a manager, under-manager,

* *Trans. Inst. M.E.*, vol. xiv., page 504.

official or deputy having a thorough knowledge of the apparatus, and also a knowledge of the workings where rescue-work is required. Non-compliance with this rule will mean exclusion from the party.

(3) The leader of a rescue-party must be appointed by the manager in charge of the mine.

(4) A rescue-party must consist of six members, namely:—(*a*) one manager or official; (*b*) one deputy; and (*c*) four other members. It is desirable, when underground, that a rescue-party shall consist of not less than four other members, besides the leader of the party.

(5) The manager or official (4*a*) must determine whether the intended work of rescue is practicable with the means and men at his disposal.

(6) Every oxygen-bottle must be tested or gauged with a pressure-gauge, before being taken away from the store at the pit or from the station. The leader of the party (4*b*) will be required to see that this is done, also that there is a proper supply of caustic soda for each breathing-apparatus.

(7) The apparatus must be carried, not worn, to some point in the pit to and from which constant intercourse with the pit-bottom can be kept up. The apparatus shall be put on and made ready for use at this point.

(8) The leader of the party must carry nothing but the breathing apparatus and an electric light. The two men following should carry any light tools that may be required if any work is contemplated, such as fixing sheets or opening doors. The two men in the rear should, in all cases, carry a light stretcher, in order that any member of the party can be easily carried back if necessary.

(9) If a sixth man is present he should carry restoratives, including two small bottles of oxygen and an indiarubber bag or bladder for inhaling oxygen.

(10) As soon as any member of the party has used up an oxygen-cylinder the party must return.

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Mr. W. E. Garforth (Normanton) said that he had great pleasure in proposing that the best thanks of the members be given to Mr. Habershon for his valuable paper. He had, with

*To illustrate Mr. M. H. Habershon's Paper on "A Joint Colliery Rescue-station."*

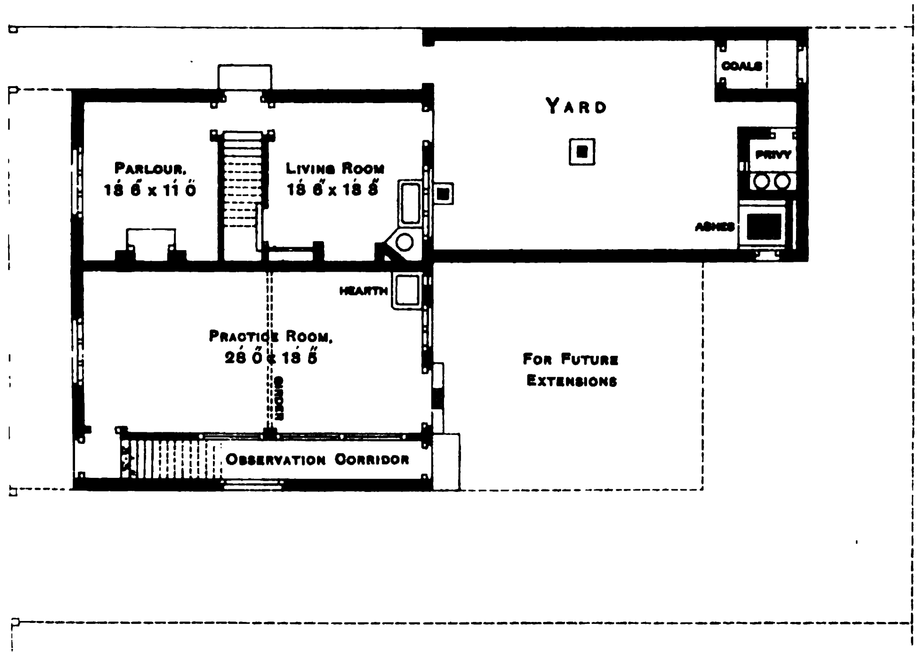


FIG. 1.—GROUND PLAN.

Scale, 16 Feet to 1 Inch.

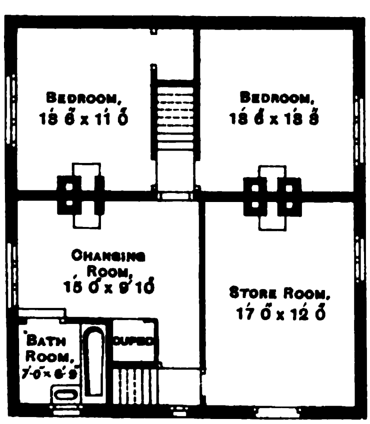


FIG. 2.—CHAMBER PLAN.

the concurrence of the Council, arranged with Mr. Habershon that his paper should be read first, and that towards the end of June, the actual experiments should be made at the experimental station at Messrs. Pope and Pearson's colliery at Normanton. The experimental drift was being made almost a facsimile of a road in a pit, after heavy falls had taken place, with a rugged pavement and confined spaces. He thought that it would afford valuable information, and they would be able to ascertain whether the rules laid down by Mr. Habershon, that intending explorers should be able to breathe in a vitiated atmosphere for a period of 2 hours, pass through confined spaces, and carry a weight, for instance the body of a fellow explorer, who might be overcome and require to be carried to the shaft, could be actually carried out. No doubt, at first, the men would be glad to go round the first and second section of the gallery, and pass out at the first outlet. In this short distance, they would be under the supervision of the men outside, their lamps would be seen through the side windows, and they would be within reach of a rope, which, on pulling, rang two bells and at the same time located the position in which the person carrying on the experiment might be. There would be considerable difficulty in maintaining the deleterious gases similar to those met with in a mine. He thanked Mr. Habershon, on behalf of the members, for the great trouble that he had taken in his paper, which would be read, not only by those who were actually engaged in the supervision of mines, but also by the workmen, who had rendered such valuable aid in the past.

Mr. H. St. John Durnford, in seconding the motion, said that he had purchased three pneumatophores, but he did not know whether they would be of any use.

The motion was agreed to.

Mr. H. B. Nash said that, if a practical rescue-station were established, where the owners could see the benefits to be derived by a local centre from which a body of men could be drawn in case of accident, to quickly restore ventilation and other matters in connection with an explosion at their own collieries, they would not hesitate to unite in sections and establish stations throughout the whole of the South Yorkshire district. The members were greatly indebted to Mr. Habershon for the care

that he had taken in putting before them so valuable a paper, with every detail carefully worked out.

The PRESIDENT said that there was a vast difference between using a pneumatophore in a room without excitement and under normal conditions as to temperature, and climbing over falls of stone, and through contracted spaces in the roadways. He would expect that the excitement would shorten the period in which a person should be permitted to use a pneumatophore. He remembered going down Bagillt shaft, when it was being sunk by compressed air and saw the marked difference in the effect upon the workmen employed. But that sinking was very different from conducting experiments in a foul atmosphere, and the arrangements should be well considered.

Mr. W. E. GARFORTH thought that, in the lower part of the Bagillt sinking, only 3 per cent. of the workmen were able to withstand the pressure, while 40 or 50 per cent. of the men were able to do so at the beginning.

Mr. M. H. HABERSHON said that there had been a great deal of practical work done in Westphalia and other parts of the Continent with pneumatophores, and the German press contained information as to the results of these experiments. Analyses had been made of the air from the apparatus, after men had been using it for 1 or 2 hours, or longer, and the proportion of carbon dioxide had never exceeded 8·2 per cent.; and in no case had the effects been detrimental to human life.* The volume of compressed oxygen was sufficient to support life for 6 hours in an ordinary atmosphere. Of course, if men breathed naturally when excited the oxygen would last longer, but men used more oxygen when excited.

## DISCUSSION OF MR. A. T. THOMSON'S PAPER ON "UNDERGROUND ELECTRIC HAULAGE AT MANVERS MAIN COLLIERIES."†

Mr. A. T. THOMSON, replying to questions asked at a previous meeting, said that the shaft was dry, and he had no fear of

* *Trans. Inst. M.E.*, 1900, vol. xix., page 543.

† *Ibid.*, vol. xx., page 29; and vol. xxi., page 75.

moisture breaking down the insulation. In the few cases where stress had come upon the cables, the cleats had readily drawn away from the props, and allowed the cable to fall, and so removed the strain. The switches at the pit-bottom had been found useful: the cables having been tapped at that point for an electric pump; and in case of a breakdown in any of the roads—no one being present near the other switches—the current could be switched off at the pit-bottom. The switches at the junctions would be useful in case of accidents to the cables leading to the motor-station, for instance—one motor might be cut off, and the other left on. The switches placed in front of the motors were only used as emergency-switches; and when the switch-boards, or electric motors, or appliances about the station have to be examined, they can be examined with safety instead of being examined when the circuit is alive. The field-magnets were left excited throughout the working-day as a matter of convenience. The reversible motor had been useful in such cases as a "flat" in the way, when pulling the rope for coupling, etc. The switches were ordinary link-switches, with cut-outs and fuses in gastight cases.

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## DISCUSSION OF MR. W. HUTTON HEPPLEWHITE'S PAPER ON "THE HEPPLEWHITE TAPERED PIT-PROPS AND BARS."*

Mr. H. St. John Durnford asked whether any member had used tapered props. They had been very highly recommended, but they did not appear to have been used in the South or West Yorkshire districts.

Mr. J. R. Robinson-Wilson (H.M. Inspector of Mines) said that he had recently seen partly tapered pit-props in use at a West Yorkshire colliery, and was advised that they had been employed for at least 40 years.

The President said that mining engineers were using tapered props, and these must be economical, or their use would have been discontinued. Two collieries were using tapered props with excellent results.

* *Trans. Inst. M.E.*, 1899, vol. xix., pages 8 and 106; 1900, vol. xx., pages 214 and 264; and 1901, vol. xxi., page 55.

Mr. C. Snow said that he had successfully used tapered stretchers, where the sides closed in very badly. The tapered ends bruised, and by so yielding before the closing sides of the road-way, prevented the stretchers from being broken in the middle. He had little doubt that an ordinary stretcher, with full-sized ends would have been speedily broken, under similar conditions.

The President suggested that tapered props should be tried in the Barnsley seam.

Mr. A. T. Thomson said that tapered props were being tried at two or three collieries.

# NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE GRAND HOTEL, HANLEY, MAY 13TH, 1901.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

## THE LATE MR. W. WOODALL.

The PRESIDENT (Mr. W. N. Atkinson) said that since their last meeting they had lost, by the death of Mr. W. Woodall, one of their past-presidents, and North Staffordshire had lost one of its most worthy and honoured inhabitants. Mr. Woodall was a man of wide sympathies and culture, and as a Member of Parliament and of the Government he had rendered great services to his country and was a watchful guardian of all the interests of North Staffordshire. Mr. Woodall was interested in mining, not only as a Member of Parliament with many miners among his constituents, but also as a colliery-owner, and he was an arbitrator for the North Staffordshire Miners' Permanent Relief Society. He was a firm supporter of educational progress and had rendered valuable service on a Royal Commission on Technical Education. In his inaugural address as President of this Institute in 1887, he urged the necessity for greater educational facilities in North Staffordshire. He moved that a letter of condolence be sent to the family of the late Mr. Woodall.

The vote was unanimously adopted.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

ORDINARY MEMBERS—

Mr. W. FREEMAN, Engineer, Florence Colliery.
Mr. JOSEPH WAIN, Manager, Ubberley Colliery.
Mr. E. WRIGHT, Blast-furnace Manager, Apedale.

ASSOCIATE—

Mr. HENRY SUTTON, Under-manager, Biddulph Valley Collieries.

## DISCUSSION OF DR. C. LE NEVE FOSTER'S REPORT ON "METHODS OF PREVENTING FALLS OF ROOF ADOPTED AT THE COURRIERES COLLIERIES."*

The PRESIDENT (Mr. W. N. Atkinson) said that the system of timbering at Courrières collieries and the method of supporting the roof by the temporary use of iron bars were described in two official reports to the Secretary of State. The system had been devised, in so far as it related to the working-faces, to suit the methods of working prevailing at Courrières collieries. The result of the adoption of this system, in conjunction with increased supervision, had been extremely favourable on the death-rate from falls, which had been reduced from 0·76 per 1,000 persons employed belowground during the ten years 1870-1879, when the system was not in operation, to 0·15 per 1,000 for the 10 years 1890-1899, during which the system was in force. He saw no reason to doubt that this large reduction in the death-rate was chiefly or entirely due to the methods of supporting the roof adopted at the Courrières collieries, and without the confirmation of statistics he thought that a considerable reduction might reasonably have been anticipated from the enforcement of such a system. It was true that there were some British collieries which, on a narrower basis of persons employed and number of years, showed a death-rate as low or slightly lower than the Courrières collieries, but this did not affect the comparison between the results obtained at the Courrières collieries during the different periods. He had nothing to add to the details of the Courrières system, as described in the official report.† He exhibited specimens of the strata forming the roof and floor of the Louise coal-seam, where he saw the system in operation, and also a section of the small girders used at the Lens collieries in lieu of the solid bars used at the Courrières collieries. The Courrières system of supporting the roof was deserving of careful and impartial consideration on its merits, and not with the idea that it was advanced as being applicable to all mines or to any special class of mines. A number of seams were worked at the Courrières collieries and they had roofs of varied character: some good and some bad. The specimen shown was from a bad roof; it certainly could not be called a good roof.

* *Trans. Inst. M.E.*, vol. xx., page 164.

† *Report of Four Inspectors of Mines on the Methods of Preventing Falls of Roof adopted at the Courrières Collieries*, 1901.

Mr. E. B. WAIN said that the results obtained at Courrières collieries were undoubtedly satisfactory, but it was pleasant to note that four of H.M. inspectors of mines had been able to find in four or five collieries working under ordinary conditions, without the special precautions taken in these particular collieries, practically equal results. The system that had been adopted at Courrières collieries was undoubtedly a perfect one for the particular circumstances of the mine; but the point which struck one was that the coal was not worked in any extended form as in ordinary mining practice. He meant that the coal was got by the pick and not holed or blasted, so that it was possible in such circumstances to follow on very closely the coal-getting with the timbering. What the effect of that was—what percentage of round coal was obtained—he did not know; but he should rather gather from what was said about this particular system of working in the report that it would be 70 or 80 per cent. of small and 30 to 20 per cent. of round coal. Such a result would be ruinous to any colliery-owner in this country, and it would be obtained if they worked the coal on the same system. He found the system required that the timber and bars must be set parallel to the face of work. It would be quite impossible to adopt any such system of timbering in a longwall face, as the moment that the sprags were drawn all the parallel bars would be swept away. He thought that he might take credit for being the first colliery-manager in this district to establish a code of rules for systematic timbering. It was many years ago, and that code had been found to be satisfactory—not preventing fatal accidents altogether; but for ten years the statistics showed results very little different from those of the Courrières collieries. It was absolutely necessary that there should be a system of timbering at every colliery (though it might not be possible to apply precisely the same system to every colliery), and it would lead to improvement with regard to the number of accidents from falls.

Mr. W. STATHAM remarked that no method of timbering could be devised which would be applicable under all conditions. He was of opinion that timber could not be set in the way recommended in many ironstone-mines, more especially if it was worked to the rise. In ironstone-working, the mine was blasted down in lumps of 4 or 5 tons, which would knock out the timber, and

become a great source of danger. Nevertheless he thought that the scheme was worthy of the earnest consideration of mining-engineers. There would be some danger, especially where the workings were driven to the rise of the mine: the timber, being set parallel to the working-face, would be knocked out when a shot was fired, and if the workmen returned before the smoke was cleared away an accident might occur. The roof would most probably fall, in consequence of the timber being removed by the firing of the shot. He thought that there would be more accidents from falls when the working-face was driven to the rise than on the strike of the seam, because the timber would be more easily knocked out in the former case than in the latter case.

The PRESIDENT replied that that point had not been raised or considered by his colleagues or himself. He supposed that there would be greater danger from falls in working to the rise than on the level. The coal-seams at the Courrières collieries were so tender that they could be worked without blasting, and big falls of coal were not likely to occur at the face. The coal was not of the same strong nature as the North Staffordshire seams. There was little spragging, and the risk of timber being knocked out by the removal of sprags or by blasting or big falls of face was not great. He conceded that no system of timbering could be devised that would be applicable in every case, but still there was the fact that at the Courrières collieries, employing from 4,000 to 5,000 men underground in ten large pits, there had been a very great reduction in the loss of life from falls. The managers of adjacent collieries were so impressed that they were adopting the same system of timbering, and it was possible that it would be further developed in France. There was an idea that the authors of the reports desired to press this system of timbering forward as being generally applicable to all mines in this country; but the authors of the reports never entertained such an idea. Much of the criticism seemed to be based to some extent on a mistaken view of the facts, especially as to the statistics. For instance, it was stated that "in a British colliery, drawing 10,000,000 tons of coal during the 10 years ending 1898, the average death-rate per 1,000 persons employed underground was 0·04 compared with 0·15 at Courrières colliery, and the average death-rate per 1,000,000 tons was 0·10 as against 0·39 at Courrières. The system of timbering at this

colliery was very efficient; the accidents, as a rule, at the face were such as could not be guarded against, and were very few in number—there had been only 1 fatal accident during the 10 years."* The same speaker made his calculations on that basis, but he went on to show that there had been 12 other fatal accidents due to falls during the same period, all of which should have been included in his calculation.

Mr. G. H. Greatbach did not think that the Courrières system was applicable to coal-mines in North Staffordshire, where they had deep holing, and the coal was blasted. The moment that blasting took place, the facing timber came down. The same occurred in an ironstone-mine, as the stone when blasted knocked out the chocks, although set 9 feet from the face. The system might be suitable for French mines, but he did not think that it was applicable to the seams of the North Staffordshire district. In many places after blasting, dodging-posts were set, as there was no chance of setting bars. The adoption of systematic timbering applicable to each seam would yield results equally as low as the Courrières system.

The President said that some timber would be knocked out under any system. The seams at the Courrières collieries are inclined at different angles, some are working at 30 degrees, others at 60 degrees, and other places nearly flat. The stepped longwall system of working was generally adopted.

Mr. E. B. Wain asked whether the roof at Courrières collieries broke down in large masses, or broke into more or less small pieces.

The President replied that the stone fell principally in small pieces, and not in big blocks. A larger proportion of light timber was used at the Courrières collieries than in Great Britain, but they had stronger timber which could be used when required. The poles were light, about 7 inches in circumference, and about 2¼ or 2½ inches in diameter.

Mr. J. T. Stobbs asked whether each man or each place was supplied with a set of bars.

The President replied that each collier was supplied with

* *Trans. Inst. M.E.*, vol. xx., page 170.

three bars, and the men working on each road were supplied with stronger bars.

Mr. E. B. WAIN said the use of iron bars was not uncommon in longwall workings. They had been used in Derbyshire and Nottinghamshire for many years, but they were set at right angles to the face-line. They were supported at both ends, by props set at regular intervals, 4 or 5 feet apart.

The PRESIDENT said that the wooden bars were practically replaced by iron bars. At one colliery in France, nothing but iron was used for supporting the roof. He did not know whether the system was successful, or how long it had been in operation.

Mr. W. L. HOBBS asked whether the timber was withdrawn at the Courrières colliery?

The PRESIDENT replied that to a large extent it was not withdrawn.

Mr. W. L. HOBBS thought that it would be more difficult to withdraw large bars placed parallel to the face-line than ordinary drift bars placed at right angles.

Mr. G. H. GREATBACH observed that none of the timber was withdrawn, because it did not pay to draw it, and not for reasons of safety.*

The PRESIDENT said that when at the Courrières collieries, he was told that the timber as a rule was not drawn, because it did not pay to get it. This was to him an unexpected answer, considering the importance which was in this country attached to the withdrawal of all timber. It might be that the complete packing of the gob might affect the question. It would be interesting to know whether the same practice had led to similar results in this country. The average cost of timber at the Courrières collieries was 8½d. per ton, exclusive of the cost of setting (which is included in the tonnage price) and the maximum cost was about 1s. per ton. The question of packing gobs appears worthy of more consideration than it generally receives in this country. When we consider the immense spaces left vacant by the extraction of the coal, a large proportion of which space it

* *Report of Four Inspectors of Mines*, page 7.

would be advantageous to fill up, it appears incongruous to draw from the mines large quantities of débris to encumber the surface. Gobs are packed full when sufficient waste-material is produced at the working-faces, and in exceptional cases débris is conveyed from other parts of the mine or from the surface. When the gobs are filled up it is found that the condition of the roads and working-faces is much improved, and damage to the surface is also prevented or greatly diminished. Whether these advantages would repay the extra cost of filling the gobs would depend on various conditions. To give the system a fair trial might involve modifications in the methods of working, and in some cases initial outlay for plant would be necessary. It appears questionable whether the system has been sufficiently tested in this country to ascertain to what extent it might be profitably carried out. In his experience, where the gobs were packed full, the roof, working-faces and roads were easier to maintain, and altogether there was a marked improvement.

Mr. G. H. Greatbach said that, if he were opening a drift or driving a breasting level, he would pack the gob for certain distances, and when he came to drift from that road he would erect sufficient pack-walls of solid dirt to the rise of the road, and from that he would form his wastes. In his experience, whenever there was an excess of dirt, and the pack was filled solid, a portion of the face would be lost if a heavy weight came on. In some seams it was impossible to work the seam satisfactorily or get the face into order, until there had been a heavy weight, and it had fallen in the gob. In the Ash coal-seam, if the wastes were open, the face was never lost; but if they were solid, the face was frequently lost.

Mr. P. J. Brennan said that his experience tended to confirm Mr. Greatbach's opinion. He found that whenever the wastes became small, because they had too much material for packing, if the weight came on, it took the face.

Mr. E. B. Wain considered that Mr. Greatbach's lot had been cast in pleasant places, with unusually thick seams and good roofs. In a coal-seam, 7, 8 or 9 feet thick, however well packed, the weight of the loose material forming the pack would cause the wall to sink from the roof and prevent such solid packing as might be made in seams 3 to 5 feet thick.

Mr. G. H. Greatbach said that he was working a seam, 3 feet thick; it was packed solid with satisfactory results, but the system was not applicable to all seams.

The President said that he was not altogether convinced that even in a thick seam, generally speaking, solid packing of the gob would not be advantageous. There were exceptional roofs and circumstances that might render it otherwise; but he was still inclined to the opinion that solid packing of gobs would generally yield advantageous results.

Mr. E. B. Wain remarked that if the solid packing of thick seams could be assured, good results would probably be obtained; but in a seam with a strong roof and a strong floor, where there was no crush and the pack-walls were built 7 or 8 feet high, no matter how well packed, there would be subsidence of the pack itself.

Mr. W. Statham agreed with the President that it was better to pack the gob solid if they could. He was working seams of coal and ironstone, 6 or 7 feet thick, and unless the gob was wholly filled, they suffered loss in the roadways and the working-faces.

# CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

## GENERAL MEETING,

HELD IN THE UNIVERSITY COLLEGE, NOTTINGHAM, APRIL 13TH, 1901.

MR. MAURICE DEACON, PRESIDENT, IN THE CHAIR.

The election of the following members was announced:—

MEMBER—

Mr F. M. PERKINS, Mining Engineer, c/o Messrs. Erdmann & Sielcken, Soerabaya, Java.

ASSOCIATES—

Mr. RICHARD BEXTON, Under-manager. Sutton Colliery, Sutton-in-Ashfield.
Mr. E A. BROADHEAD, Enginewright, Sutton Colliery, Sutton-in-Ashfield.
Mr. G. E. COLLIS, Deputy, Chapel Road, Grassmoor, Chesterfield.

The SECRETARY read the balloting list prepared by the Council for the election of officers for the year 1901-1902.

The SECRETARY, on behalf of the Council, gave notice of proposed alterations of the rules.

A paper by Messrs. GEORGE and G. C. FOWLER on "Systematic Timbering at the Babbington Collieries" was read as follows:—

# SYSTEMATIC TIMBERING AT THE BABBINGTON COLLIERIES.

By Geo. and G. CARRINGTON FOWLER.

The systematic or regular spacing of timber at the coal-face has been the rule at the Babbington collieries for the last 25 years.

At about that time, or a little later, one of the writers of this paper had a few simple rules printed, pasted on boards, and varnished. One of these boards was hung at the gate-end of every stall, and by this means it was possible to vary, if desired, the spacing of the timber in the different seams at work, or in different districts of the same seam.

The perpetually recurring additional rules and regulations emanating from the legislature and the Home Office made one of the writers nervous as to the propriety of drawing up rules, and the little boards dropped out of use, but that they have existed may be put on record.

There is some difference of opinion as to the advisability of formulating rules for the spacing of timber, and many able engineers think it best to leave every miner free to follow his own judgment. No doubt miners are a highly intelligent set of men but *errare est humanum* and an occasional slip may cost a man his life; whereas there is nothing to prevent an additional prop from being set if the prescribed spacing be not close enough.

As to the distance at which propping should be spaced, the writers are of opinion that, from the standpoints of economy of labour and cost of material, close timbering is most satisfactory. The distance apart from prop to prop in the Top Hard coal-seam at the Babbington pits is 3 feet 6 inches on the line parallel with the face, and they are both easier to move and less liable to break if they are set at this distance, than if the spacing is wider.

It may be of interest to the members to know that the whole

of the propping in the coal-faces at these collieries is done with steel props of H section, weighing 50 pounds to the yard, and fitted with ends as shewn in Figs. 1, 2 and 3 (Plate V.). The steel props, which were first used, were made by cutting out 2 inches of the web of the girder and turning over the top and bottom flanges, but the head so formed was found to be much weaker than the rest of the prop: consequently an iron cushion was introduced, which makes the prop practically indestructible.

In some experiments which have been recently made as to the crushing strength of these props an unexpected gain by the use of the cushion was discovered, as shewn in Table I. No doubt the enhanced strength is due to the line of the crushing-resistance of the prop being by this means kept truly central to the axis of the prop.

TABLE I.—SHEWING THE CRUSHING-RESISTANCE OF FIRTH STEEL PROPS.

| No. of Experiment. | Length of Prop. | Section of Prop. | Weight of Prop Per Yard. | Crushing-resistance of Prop. | |
|---|---|---|---|---|---|
| | | | | Without Cushion. | With Cushion. |
| | Feet. | Inches. Inches. | Pounds | | |
| 1 | 7 | 5 by 4 | 50 | 77 | 90 |
| 2 | 6 | 5 ,, 4 | 50 | 91 | 98 |
| 3 | 5 | 5 ,, 4 | 50 | 98 | 99 |
| 4 | 4 | 4 ,, 3½ | 38 | 72 | 82 |

It is not quite the intention of this paper to discuss the matter of timbering from the monetary side of the question, but in the opinion of the writers the equipment of a colliery with a full set of steel props will pay good interest on the outlay.

If steel props are well and frequently set, and steadily marched forward as the stall-faces advance, the working of the coal is much simplified and improved.

The diagrams shew how the props are set and how, as the faces advance, a fresh row of props is fixed, giving space for a tram-road along the bank-face, and also how the props are withdrawn and packs substituted (Figs. 4 and 5, Plate V.). Two rows of props are always maintained at the bank-faces and those in the wastes and roads are not withdrawn until the packs are

topped. The coal is worked on the Nottinghamshire system of longwall, as illustrated in Fig. 6 (Plate V.), the faces being kept as much as possible in a straight line.

The barring in the banks at these collieries was more or less in operation, when one of the writers took up the management nearly 30 years ago. In several parts of the Babbington pits, it was and is practically impossible to get the coal without it, as in those parts of the mine a weak and rotten clod (locally called *lommy*) 3, 4 and 5 feet in thickness or more, is interposed between the seam and the usual roof of the Top Hard coal-seam (Fig. 8, Plate VI.).

The practice originally in vogue was to use sawn bars, 3 or 4 inches in thickness and 6 or 8 inches in width, but these were constantly breaking and were expensive to replace. This circumstance determined the writers to try a flat bar of wrought iron in place of the wood, and the general custom has been to make these bars 5 inches wide and 1¼ inches thick. The bars are set as shewn in Figs. 7, 8 and 9 (Plate VI.). If they become badly bent by heavy strains they are sent to the surface, warmed and restraightened, which is done without material difficulty. When the coal is holed and worked with a buttock, bars are set as the loader advances, and thus he always works under an iron-supported roof.

In the stalls where the coal is worked to the sline, temporary props, marked *x*, *x*, (Fig. 7), are pushed forward as the wall is advanced, the workman himself being more or less protected by the regular timbering.

If the condition of the coal-face favours it, bars are stamped into it, in order to leave as little roof unbarred as possible. These bars are fore-set, while more coal is being removed. Finally, props are fixed under the front ends of the bars, and the fore-sets are removed. When the bars are set, the temporary props, *x*, *x*, are withdrawn.

Fig. 9 (Plate VI.) shews a set of steel props, cushions, and a bar, as used in stalls; *d* is an iron or steel bar fixed on two steel props, *e*, *e*; *f*, *f* are pieces of wood used as pads; and nogs of wood, *g*, *g*, make up for unevennesses in the floor.

Fig. 1 (Plate V.) is a side view of a steel prop, *e*, set on a nog of wood, *g*, and capped with a hard wood lid, *k*, 3 inches deep, 4 inches wide and 16 inches long.

Fig. 10 (Plate VI.) shews a set of timbering in a road-way. The steel girder, *a*, weighing 72 pounds per yard, is set on Norway timber, *b*, *b*, with wooden pads, *c*, *c*; and slabs of wood, *s*, *s*, which reach from bar to bar.

In conclusion, it is submitted by the writers that, considering the conditions under which the mine is worked, the death-rates, as shewn in Table II., compare very favourably with both British and foreign practice.

TABLE II.—SHEWING THE DEATH-RATES BY FALLS OF ROOF AND SIDE DURING THE LAST 20 YEARS AT THE BABBINGTON COLLIERIES.

| Periods. | | 1880-89. | 1890-99. |
|---|---|---|---|
| Persons fatally injured ... ... .. | No. | 3 | 3 |
| Mineral worked ... ... ... ... | Tons | 4,381,009 | 5,854,013 |
| Average Death-rate per 1,000,000 Tons | No. | 0·68 | 0·51 |
| Average Number of Persons employed | No. | 893 | 1,381 |
| Average Death-rate per 1,000 Persons employed Underground per Annum ... | No. | 0·33 | 0·21 |

The writers give the following details of the six cases, where death occurred from falls of roof and side, during the last 20 years at the Babbington collieries.

In 1885, Geo. Rowland was killed whilst cleaning-up at the face, and getting it ready for the holers to start holing. A piece of roof fell from between the face and the line of timber. He was deaf, and no doubt would not hear any warning that the roof generally gives just before a fall. The accident occurred in the Kimberley pit.

In 1887, Thos. Wheeldon was killed in the Cinder Hill colliery. He wrongly took out a prop below a piece of clunch, commenced to hole under it, without putting up another prop in its place, and the clunch fell upon him.

In 1888, Enoch Aran was killed at Bulwell colliery. He was taking down an old bar in the main road, when a piece of bind, that was resting on the bar, slid off and rolled upon him.

In 1890, Arthur Hill was killed at Cinder Hill colliery. Whilst raking coals at the face, a sline of coal rolled over, and pinned him against a prop.

In 1891, George Pinder was killed at Cinder Hill colliery. Whilst ripping up the side of a fault in an airway, a piece of roof fell upon him. He lived some months afterwards, and it is doubtful whether this accident caused his death, as he had suffered for years from some disease of the bladder.

In 1894, Frederick Clarke was killed at Cinder Hill colliery. He was loading coals at the face, and some roof fell upon him.

It will be seen from the preceding cases, that the accidents at the face in which the method of timbering is material to the results in the period of 20 years are only four.

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The PRESIDENT (Mr. M. Deacon) said that, at the present time, much attention was being paid to the consideration of the possible manner, or manners, in which the number of accidents from falls of roof might be reduced. As far as he could judge, the method of timbering at the Babbington collieries was, to a very large extent, similar in its principles to the method adopted at the Courrières collieries; and although there might be points of difference, the principle was practically the same. No doubt, many engineers had used iron bars for supporting the roof, and he had used them himself, when he had found it needful. It seemed to him, however, that it was necessary to decide whether all roofs were so bad as to require special timbering; and to what extent they could foresee the need for adopting a method of timbering, or supporting the roof by means of iron bars, which would assume that the roof was in all cases bad. Engineers had to consider this matter not only with regard to the safety of the men (and that was, of course, the primary consideration) but also with regard to the commercial working of their collieries. Mr. Fowler had not told the members the cost of timber at the Babbington collieries, but they had heard that at the Courrières collieries the cost was much higher than they would like to pay in this country; and if the timber cost were the same in this country as at the Courrières collieries, many mines would be closed. He was quite confident that anything they could learn from such interesting papers as the one to which they had just listened, including the example of

To illu ering at the Babbington Collieries."

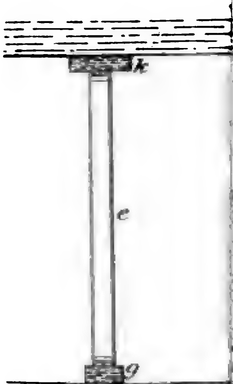
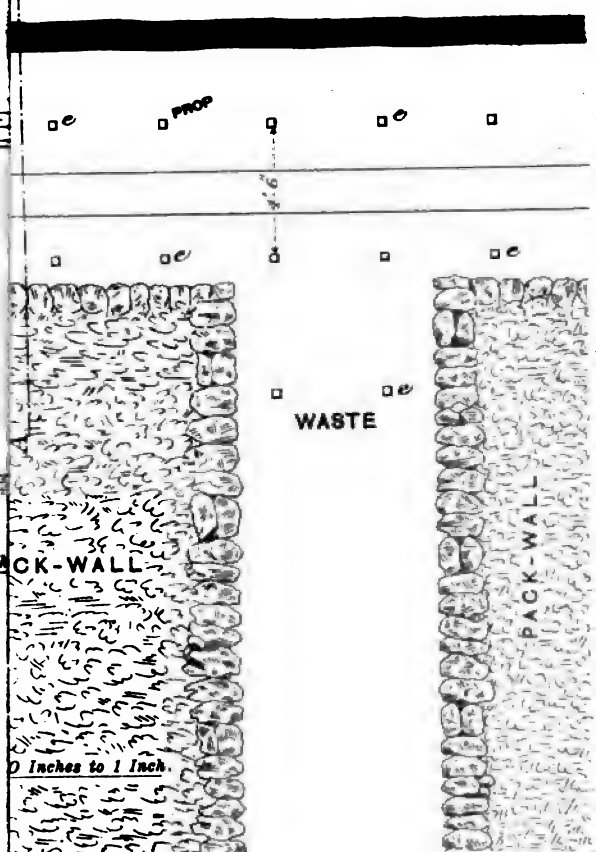



Fig. 1.

Scale, 40 Inches to 1 Inch




0 Inches to 1 Inch.

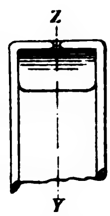



Fig. 2.

Fig. 4.

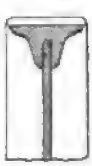
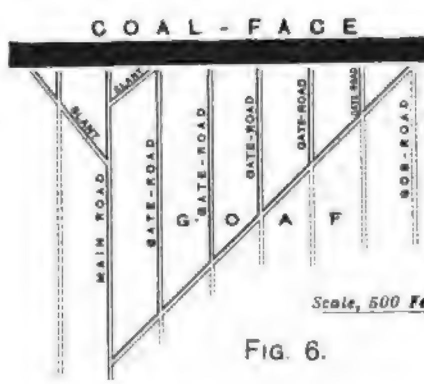


Fig. 3.—Section thro
Line Y.Z of Fig. 2

D
AM

Scale, 10 Inches to 1 I

RT

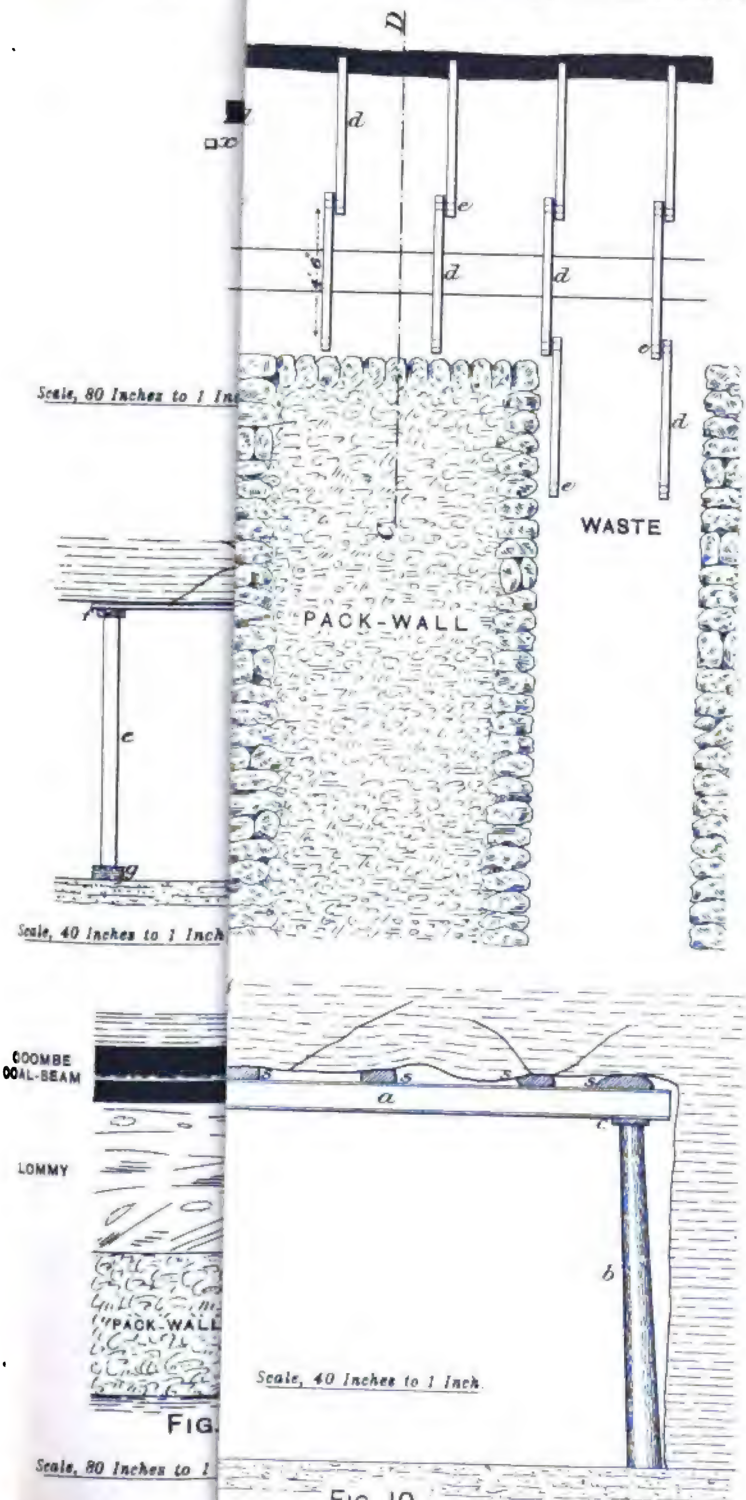



Scale, 500 Feet to 1 Inch.

Fig. 6.

Andw Reid & Compy Ltd Newcastle on Tyne.

To illus bering at the Babbington Collieries."




Scale, 80 Inches to 1 In

Scale, 40 Inches to 1 Inch

FIG.

Scale, 80 Inches to 1

Scale, 40 Inches to 1 Inch.

FIG. 10

French engineers, would produce in the minds of the members a strong desire to benefit, as far as it was possible, from the information contained in Mr. Fowler's paper.

Mr. G. Elmsley Coke (Nottingham) said that the main difference between the plan adopted at the Babbington collieries and elsewhere was summed up in Mr. Deacon's remark that "he had used them himself, when he had found it needful." At Cinder Hill and Newcastle collieries, the bars and props are set at regular intervals, and it certainly appears to be a capital plan for keeping up the clod.

Mr. G. J. Binns (Duffield) said that he had recently visited the Lens and Courrières collieries, and he hoped to add to the discussion at a future meeting. He had found the following reference to systematic timbering in Mr. J. Callon's *Lectures on Mining**: "when isolated props are insufficient to support a roof which is apt to break into small pieces," . . . . "It is employed in many collieries in the North of France and in Belgium, where it is necessary on account of the brittleness of the roof, in order to obtain the coal sufficiently clean." The initiation of the system seemed to be due to the desirability of maintaining the roof, because it was so bad that pieces of it fell among the coal and damaged a valuable fuel. Some of the seams in the North of France were inverted, the floor becoming the roof and the roof the floor. The coal at the Courrières and Lens collieries was very much crushed, and full of slickensides and slips, and the roof also partook of the same character. The coal was worked under circumstances which did not prevail in this country.

He would like Mr. Fowler to give his opinion on the disadvantages, if any, of using props which would not give way, in contradistinction to props which did give way, and on that account promoted the safety of the men and economy of timber.

Mr. A. H. Stokes (H.M. Inspector of Mines) said that safety and cost interested the members. These were pre-eminently the two things which were constantly before them. The cost of timbering at the Courrières collieries was 8d. per ton; and he

* Translated by Dr. C. Le Neve Foster and Mr. W. Galloway in 1876, vol. i., pages 236 and 237.

visited a colliery some time since, where the cost of timber was said to be 1s. 2d. per ton. The cost of 1s. 2d. per ton had not shut up the colliery to which he had referred, and he did not know that systematic timbering in that district would close any collieries.

No doubt, it was said, systematic timbering was wanted where the roofs were bad, but he asked whether the high death-rate was caused by bad roofs? Unusual precautions were generally taken where bad roofs existed, and it was the other kinds of roof which enhanced the death-rate—those in which it was left for someone to say, "where necessary." Was the collier, the loader, the deputy or manager, to say "where necessary"? If an order was issued and timbering made systematic, there was no "where necessary," until after the systematic timber had been set. The object of systematic timbering was not to leave it to anybody to decide where it was necessary, but to enact that timber should be set at certain definite points or distances, and after this was done, if it were needful to set more timber, then more timber must be set.

He would like to know how many times the steel props were renewed or taken out for repairs, as there was a great difference between a 5 feet and a 7 feet prop in that respect. Mr. Fowler had been very successful in reducing the death-rate which was very low, still, there were other pits in the district which had a low death-rate, but they were systematically timbered, although not in the same way. One colliery had raised many million tons of coal, and in thirteen years only one man had been killed from a fall of roof. Why should not systematic timbering be adopted at all collieries, whether the roof was good, bad or indifferent? If the roof were bad, he supposed they would do it in any case; if it were indifferent, it was all the more necessary to timber it systematically; while if it were good, it would only mean setting the bars and taking them down again, but they would have served their purpose of protection.

Mr. Alfred Chambers (Eastwood) said that the use of steel bars did not eliminate every element of danger; and if the coal were not worked very fast, the bars would cut and damage the roof and cause falls, where otherwise the roof would be tolerably adhesive. He also found that they could not adjust the cushions to yield sufficiently when the working-face moved comparatively slowly. It is noticeable that the most skilled workmen, when

contending with a bad roof, rely on additional props with increased length of lids in preference to bar-settings, as the bank-weight settles unequally on bar-settings, distorting the setting, and causing one of the two props to be unreliable. It is never safe to trust to the protection of a bar-prop when a sline of coal dashes up against it. A single prop with a lid-setting is a reliable factor, receiving in due time its share of the weight, being clear of the distorting effect produced through the connexion of a bar to a prop receiving a more intense weight.

Mr. G. J. Binns said that Mr. Fowler divided his statistics into two periods, and there was a very striking reduction in the fatalities during the later period—a reduction of 36 per cent. on the men employed, and 25 per cent. on the tonnage. Was there any particular cause (such as an extension of the system) to account for the decrease, and was the system as much in vogue during the first period as during the second? And was there any suggested reason for the decrease, other than the general causes which had contributed to the improvement that had taken place in most death-rates during the past few years? At the Courrières collieries, there had been a striking reduction in the accidents from falls, but there had also been a striking reduction in other accidents.

Mr. G. E. Coke said that the increasing cost of coal was a very important factor in our foreign trade.

Mr. G. Spencer (Mapperley colliery) said that he understood there was a general system of timbering practised at every colliery as required by the Coal-mines Regulation Acts. The adoption of any extended system no doubt rested with the management, but if additional timbering were required to meet the exigencies of any particular roof, he thought it ought to be done by the men in the stalls, or by the under-officials. He had used iron or steel bars for 14 or 15 years, and on comparing his system with that in use at the Courrières collieries—additional short bars should not be used with that system—he saw no reason, in the case of a bad roof, why short bars should not be placed parallel to the face, in addition to the present steel bars, set at right angles to the face.

Mr. H. Richardson Hewitt (H.M. Inspector of Mines) said he was glad to see that at Babbington collieries, a distance for

setting timber every 3 feet 6 inches had been adopted. Too much space was frequently left unsupported at the coal-face, and some managers allowed the distance between props to be 6 feet. He thought that, in so-called systematic timbering, the bars should always be set at the coal-face, and the roof should not be supported by props only, as was done in some districts at the Babbington collieries. In advance of the last bar, a prop should be set for the protection of the loader until the next bar and its supporting timber was set, when this safety or catch-prop should be removed. He would like to see more frequent inspection of the working-places by officials at some mines, as he believed such additional visits by officials would be advantageous from the point of view both of safety and economy. The difference in the costs of timber at the Babbington and Courrières collieries, was caused by the timber being allowed to remain in the workings at the latter colliery, whereas at the former everything was withdrawn. It seemed a great waste of material to leave timber in the goaf, and in this district particular care was taken to ensure that all timber was withdrawn, for reasons well known to most engineers. There are no accidents at Courrières collieries, while withdrawing back timber, or while standing in the goaf to build pack-walls, as all débris is turned over into the goaf, and no pack-walls are built. Both of these employments are causes of accidents in this country.

Mr. C. SEBASTIAN SMITH (Shipley collieries) asked what was the number of times that steel bars could be used over again. In his experience great difficulty arose from the breaking of the ends of the bars, thereby making a considerable number of them practically useless for re-setting.

Mr. W. HAY (Shirebrook) observed that at Stanton colliery, mild steel bars, 5 inches wide, $\frac{3}{4}$ inch thick, placed $4\frac{1}{2}$ feet to 5 feet apart, and set at right angles to the line of the working-face had been used for 9 years. Only one row of bars were set at a time in each stall. During these 9 years, there had not been a single fatality from a fall of roof at the coal-face, and only 3 minor accidents. The cost of timber, including the steel bars, was about 2d. per ton. The roof of one seam of coal worked at this colliery is a stone bind, very full of slips, and the roof of the second seam is a white sandstone.

Mr. G. C. Fowler, replying to the discussion, said that the roof at the Babbington collieries was allowed to subside to some extent. The steel props were not absolutely rigid, for a lid was placed at the top and a block of wood at the bottom of the props (Fig. 1, Plate V.); and pieces of wood, *f* and *g* (Fig. 9, Plate VI.), were placed between the steel bar and the props, and between the props and the floor. These wooden blocks were crushed by the weight, and allowed a certain amount of sinking of the roof. There were about 2,000 steel bank-bars in use at one colliery, and about 60 bars were sent out per month to be straightened. At the same colliery, 11,000 steel props were in use, and 240 props were sent to bank per month for straightening. The differences in the death-rate, possibly, were in part due to increased supervision, an increase in the number of deputies, etc. The whole of the timber, both wood and steel, was taken out, as it was believed to have a tendency to cause gob-fires. The steel was used over and over again, and, since the introduction of cushions at the ends of the props, they were practically indestructible. The bank-bars were now being made of mild steel, instead of wrought iron.

The President remarked that there had been some difference of opinion as to whether steel or iron bars should be used. Mr. Fowler used iron, but of late he had used steel. He noticed that flat bars were used, and asked whether it would not be more economical to use a shallow, channel-section of bar. The object of using metal bars was not so much to endeavour to hold up the superincumbent weight of the earth's crust (which they would not succeed in doing) as to prevent the superincumbent weight from coming down suddenly and injuring their workmen. If timber would do that, and render as good service as iron and steel bars (perhaps in some cases better) why not use timber? Where there was not height enough to run the tubs along the face, where wooden bank-bars were set, then, he said, use iron bars, but individually he was absolutely opposed to any attempt to keep up a roof which must come down. It was utterly useless to try to keep up the superincumbent weight of strata, and all that they could hope to do was to let it down gradually, and to prevent it from falling upon their workmen. They did that in the packing of the goaves, but they did not leave props standing in the goaves to take the weight off the packs. He (Mr. Deacon) knew of collieries

where the cost of timber was 1s. 6d. per ton, and he would like to ask Mr. Stokes whether, when he enquired the cost of timber he also enquired what was the selling-price of the coal.

Mr. A. H. STOKES replied that the selling-price was very high.

The PRESIDENT remarked that the members knew that Mr. Stokes was referring to South Wales, but the selling-price of the best Welsh coal was nearly 10s. per ton higher than it was in Derbyshire at the present time, so that they could afford to pay a higher timber cost. He had always been under the impression that systematic timbering was used in the Midland district, where they had Special Rules providing that timber and sprags should not be set more than a certain distance apart.

When the Special Rules were formed, the combined talent of H.M. inspectors of mines and the managers was brought together to decide at what limits timber should be set apart, and it was decided that 6 feet was a proper maximum distance. Consequently, it seemed to him that in the Midland district, systematic timbering was already in use, and that the present campaign was directed against other districts. There were districts where collieries were allowed to set timber as they chose—a 2 inches prop here and a 10 inches one there—for no other reason than that of taking the timber nearest at hand, rather than troubling to set the props best calculated to do the duty required of them. In the consideration of statistics as to the number of accidents per 1,000,000 tons of coal raised, and per 1,000 men employed, every member who took an interest in this matter ought to satisfy himself as to how many of the accidents which occurred at his own collieries would have been prevented if either the Babbington system or the Courrières system had been adopted. A complete analysis of the cause of every accident from falls of roof ought to be noted and carried on from year to year, until they were able to find out how far any such new system of timbering was going to affect the number of accidents. At one pit, he had examined the record of accidents for the past 6 years, in order to ascertain how many accidents would have been prevented if the Courrières system of timbering had been in operation. During these years, there were 72 accidents, and on a careful examination of the causes of every one of those accidents he came to the conclusion that there was only one which would have been prevented by the Courrières

system of timbering. Every colliery-manager, in considering this question, ought to go into that very important point, for his experience was that a large proportion of the accidents from falls of roof arose not from the method of timbering—the systematic timbering required by the Special Rules—but from the withdrawal of props, carelessly perhaps in some cases, but in others not so—or from some cause which timbering, however systematic, would not prevent. Mr. Hay had given some interesting particulars as to one colliery, but the longer he lived the more he (Mr. Deacon) was convinced that the comparison of one colliery with another was of extremely little value, unless they knew the condition of the roof and other surroundings. In conclusion, the President proposed a hearty vote of thanks to Messrs. Fowler for their valuable paper.

Mr. A. H. Stokes, in seconding the motion, expressed a hope that at their next meeting the subject would be further discussed.

The resolution was cordially adopted.

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Mr. L. W. de Grave read the following paper on "Investigations into some Electric Accidents and the Means of Preventing them":—

## INVESTIGATIONS INTO SOME ELECTRIC ACCIDENTS AND THE MEANS OF PREVENTING THEM.

By L. W. de GRAVE.

Electric accidents may be divided into two classes:—Shock and fire.

A shock, so called, is the passage through the body of a small electric current, causing nervous and muscular contraction or cramp, and (if there be sufficient current passing for a sufficient time) the stoppage of the heart's action. The actual stoppage of the heart's action is due to the nervous and muscular contraction round the heart exerting a pressure on it. It is, perhaps, only right to say that this is not generally accepted, in the medical profession, as the cause; but there are, as will be seen later, many indications that this pressure on the heart is the cause. There does not appear to have been a previous investigation into the subject other than *post-mortems*, resulting in the stock verdict of "asphyxia or syncope due to electric shock." One hears a great deal about differences in constitutions being responsible for the more or less serious effects suffered by individuals from shocks. A close investigation shews that for the word "constitution" should be substituted the words "muscular development," as it is invariably found that an extremely muscular man suffers to a much greater extent than one of less muscular development. Several cases of quadrupeds which have been "electrocuted" and an immediate *post-mortem* (without the removal of the electric current) has shewn abnormal pressure on the heart.

Before going further, it is necessary to distinguish between an "instantaneous" and "time" shock: the former being that received when contact is made with a conductor (the position of the individual being such that he has the power of disconnecting himself instantaneously); and the latter, when, from position or cramp, the power of disconnecting himself is lost.

In the former case, there is an instantaneous nervous and muscular contraction causing a feeling as of a blow struck on the inside of the heart. In the latter case, there is a sequence of sensations depending on the voltage and time.

TABLE 1.

| Pressure in Volts. | Time interval in Minutes. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. | 4. | 6. | 7. | 8. | 9. | 10. | 11. | 13. | 15. | 17. | 18. | 19. | 20. | 21. | 22. |
| 50 | — | — | — | VS | VS | VS | VS | S | S | S | S | S | S | S | S | S |
| 100 | — | — | VS | VS | VS | VS | S | S | S | S | S | S | S | X | X | X |
| 200 | VS | VS | VS | VS | S | S | S | S | S | S | X | X | X | X | X | $X^2$ |
| 300 | VS | S | S | S | S | S | X | X | X | $X^2$ | $X^2$ | $X^2$ | $X^2$ | $X^3$ | $X^3$ | $X^3$ |
| 400 | S | S | S | X | X | X | X | $X^2$ | $X^2$ | $X^2$ | $X^3$ | $X^3$ | $X^3$ | $X^4$ | $X^4$ | $X^4$ |
| 500 | X | X | X | X | $X^2$ | $X^2$ | $X^3$ | $X^3$ | $X^3$ | $X^4$ | $X^4$ | $X^5$ | $X^5$ | — | — | — |

REFERENCES: VS is very slight muscular cramp, in reality little more than a tingling sensation; S, slight muscular cramp; X, slight muscular cramp, and a feeling of successive light sharp taps on the inside of the heart; $X^2$, slight muscular cramp, taps ceased, a slight oppression in the region of the heart; $X^3$, muscular cramp appeared less, but without any appreciable relaxation, oppression in the region of the heart increased; $X^4$, oppression in the region of the heart increased to a painful extent, and a feeling of nausea, resembling that of a slight brain-concussion; and $X^5$, a contented numbed sensation, probably the immediate forerunner of unconsciousness (safe time-limit).

It cannot be denied that even a small voltage, such as 50, will cause stoppage of the heart's action if kept on long enough; this "time," for any given voltage, may be called the "time-limit"; but for the purposes of this paper the "safe time-limit" is taken; that is to say, the length of time during which an individual can receive a shock of a given voltage without permanent appreciable injury to the system. As this safe time-limit is a most important point, and, moreover, one which can only be settled by actual experiment, the author has made experiments on himself at irregular intervals. The voltages employed, as shewn in Table I., were progressive, and for this reason, in addition to the "subject" being somewhat inured to shocks, the safe time-limit is probably higher by at least 25 per cent. than most people could stand.

There is considerable difficulty in conveying to another person any adequate idea of the sensations represented by $X^2$, $X^3$ and $X^4$.

It must be remembered, that these shocks were taken from hand to hand, direct across the terminals, and not as usually received accidentally (from one terminal and through earth) in which latter case the shock is much less. In order to explain this difference, it is necessary to consider the amount of resistance in the path of the electric current, as on that resistance depends the quantity of current which passes. The resistance of the human body varies enormously with the health, and again with the nature of the skin at the time, that is whether dry or moist.

The heavy black line in Table I., represents a change in the condition of the skin, when it became clammy; the actual current passing at the time of the tests on the right of the line will, therefore, have been greater.

TABLE II.

| | + to - dry. | To earth dry. | + to - wet. | To earth wet. |
|---|---|---|---|---|
| Resistance in Ohms. | 30,000. | 150,000. | 10,000 | 2,500. |
| Volts. | Current. | Current. | Current. | Current. |
| 50 | 0·0016 | 0·0033 | 0·005 | 0·02 |
| 100 | 0·0032 | 0·0066 | 0·010 | 0·04 |
| 200 | 0·0064 | 0·0132 | 0·020 | 0·08 |
| 300 | 0·0096 | 0·0198 | 0·030 | 0·12 |
| 400 | 0·0128 | 0·0264 | 0·040 | 0·16 |
| 500 | 0·0160 | 0·0330 | 0·050 | 0·20 |

Table II. gives the currents which would pass under the various conditions named, and it will at once be noticed that there is a big difference between the current passing from hand to hand and hand to earth.*

With this introduction, the author proposes to give details of some fatal accidents to men and horses.

* Earth, in these results, is represented by the following conditions:— Wet boots, wet ground, and an earth plate-connection, 36 inches from the feet.

## Accidents from Shock.

*Accident A.*—The deceased, 36 years of age, was of heavy build, and employed as deputy. A shunt-wound motor of $2\frac{1}{2}$ horsepower was driving (by belt) a small fan, the voltage at the dynamo was 500.

From a report of the coroner's enquiry, it appeared that: The motor and fan had been working during the night without attention other than occasional visits from the deceased, who was deputy in charge of the district. Early in the morning, deceased went to the assistant-electrician and informed him that there were some pins loose on the motor. Together they proceeded to the motor, passing on their way (at a point about 900 feet from the motor) a main switch which controlled the motor-circuit. Some conversation took place as to whether this switch should be left on or off; eventually the deceased decided to put it on, and thus save the trouble of going back to it when ready to start; to this the assistant-electrician objected, but considering the deceased as the senior in authority it was left on. At the motor there were two switches, one a double-pole main-switch, and the other the resistance-switch with automatic release. The assistant-electrician asked deceased whether both these switches were off, and deceased replied that they were. The two men then examined the motor and found some pins loose. Deceased volunteered to tighten these whilst the assistant-electrician went to oil the fan, close by. Deceased went to the back of the motor, between it and the switch (which was 6 feet from the motor and $4\frac{1}{2}$ feet from the ground), and leaning over the top of the motor commenced to tighten up the pins, when the assistant-electrician heard deceased say, "Oh, pull me off!" The assistant-electrician, thinking that deceased must be receiving a shock, and being afraid of one himself, instead of pulling deceased off, went to the main switch (which he found was just making contact) and switched it off; then going to the deceased, he lifted him off apparently dead. The assistant-electrician, in reply to the coroner, said he thought it possible that the deceased might have put the switch on with his body, in working behind the motor.

A doctor stated that he examined the body, when it was brought out of the pit. "There were two burns on the right arm, each about the size of a sixpence, which had apparently been received from the positive and negative terminals. This would complete a circuit which would traverse the whole system and produce nerve-paralysis, resulting in the instantaneous stoppage of the heart and lungs, and death from asphyxia. The deceased was a man of fine physique and very healthy. If artificial respiration had been immediately started with the application of an electric current over the heart, life might probably have been saved."

The coroner, in summing up, stated that: "It was remarkable that a current of 450 volts should kill the deceased; there must have been some idiosyncracy in his constitution. It was clearly the neglect to see the switches cut off, either at the stall-head or at the motor, that had brought about the unfortunate accident. If anybody had been there who well understood the Marshall-Hall method of artificial respiration, the deceased might have been saved, even though a few minutes had elapsed. He thought that the jury would say that the affair was a pure accident, and that the only man to blame was the deceased himself, who was the deputy in charge, and should have seen that the switches were properly turned off."

The verdict of the jury was "accidental death."

From the evidence, it would appear that the man was killed by a shock of 500 volts in a space of time of about 10 seconds. Further investigations made by the author are embodied in the following recapitulation, which, at the risk of being tedious, is necessary for clearness.

The deceased in leaning over the top of the motor (which was stationary at the time) to tighten some pins, accidentally put his arm in contact with the terminals on the top of the motor. The starting-switch and main switch were both said to be off at the time; that this was not so is evident by deceased receiving a shock; and the evidence of the assistant-electrician shews that he afterwards found the double-pole main switch partially on and the starting-switch off.

Fig. 1.

Fig. 1 shews the position in which the deceased was on the top of the motor. Fig. 2 shews, diagramatically, the electrical connections as they were at the time, and, in fact, the only form of connections possible with the apparatus in use. Following out these connections, it will be seen that with the main switch, *C*, partially on and the starting-switch, *B*, off, there would be three terminals, namely, those connected to the field-magnet (shunt) windings, on the top of the motor, having between them nearly the full pressure of the generator, 500 volts. The distance between the terminals is about 9 inches. The deceased became connected, as the marks on his arm indicate, and most of the current due to this pressure of 500 volts would pass through the right arm from point to point, some across the body to the left arm, spanner and motor-frame to earth, and some also through the legs and feet to earth, causing the usual muscular cramp, which (as he was in a cramped position) probably prevented him from getting away from the terminals,

hence his request to be "pulled off." The assistant-electrician, fearing a shock, did not pull him off, although he might safely have caught hold of the clothing and either pulled or rolled him off, feeling, if anything, only a very slight shock; he, however, in his want of experience, preferred to pull off the double-pole main switch, thus breaking the shunt field-magnet circuit. The mere fact of doing this momentarily induced a very high pressure in the coils (in the type of magnets under consideration about 1,300 or 1,500 volts), the whole of which would be discharged through deceased. Referring to the evidence, the deceased was alive after coming into contact with the terminals, but directly the assistant-electrician* went to him, after turning off the switch, he was apparently dead, that is to say within 10 seconds.

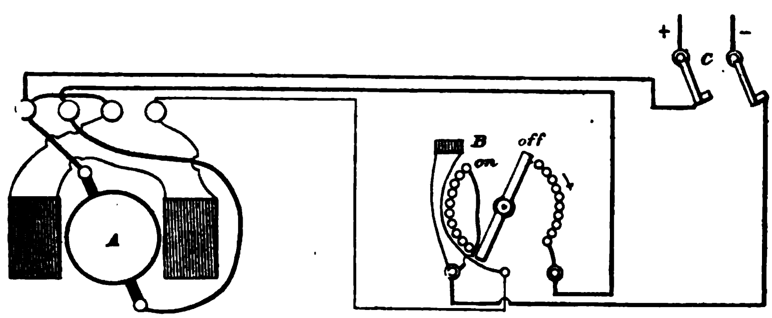


FIG. 2.

The error consisted in not seeing that the double-pole switch was off, and although the neglect of this was the cause of deceased receiving a shock, he would have escaped with a fright had he been pulled off instead of the switch being thrown off.

*Accident B.*—Fig. 3 is very nearly self-explanatory. The accident occurred at a gate-end, up to which the cables were run for a coal-cutting machine (which was not at work at the time). The trailing cables were coiled up, and there was no current in these cables, as the main switch in the switch-box was off. A voltmeter was connected on the dynamo side of the switch-box. The deceased (a powerful young man and 25 years old) ran the iron tub, he was "hurrying," off the rails, at the rail-end, into the voltmeter, cutting through the insulation of the connecting wires and

* The assistant-electrician (so called) had very slight experience, in fact, only such as a mechanic would have from looking after a motor.

making a connection through the tub, himself and earth. He was found about 20 minutes afterwards, apparently dead, with the current still passing through him, his hands resting on the tub and himself full stretch, face downwards. It is somewhat unaccountable that when first receiving the shock he should have lost the power of disconnecting himself; probably, however, this was due to the position. No attempt was made to restore respiration. The voltage was 500.

*Accident C.*—This accident at Liverpool may be referred to in connection with time-limit. It was caused by a bundle of overhead telephone wires giving way (owing to the superimposed strain of snow and sleet) falling across the trolley-wires of the electric tramway system, and down to the ground. The telephone-

FIG. 3.

wires being hard drawn, coiled and kinked, and caught some of the passers-by, and horses. It is not necessary to go into details of attempts to extricate the victims; sufficient be it to say, that anyone with a knowledge of electricity could have extricated the victims, if provided with something fairly dry to stand on, say a great coat thrown down, a piece of board or mat, an ordinary pair of gloves and a penknife to cut the wires—to say nothing of such things as indiarubber gloves, plyers, or indiarubber mats from neighbouring shops. Through the breakage of the telephone-wires the means of communication with the supply-station was destroyed, so that the current was not shut off. The car-drivers were not provided with section-keys, by

means of which that section of the trolley-line could have been disconnected. The shocks in this case were rather complicated, and made worse by the struggles of the victims. Some were marked where the wires had touched the skin, but the shock would be general all over the body, through the clothes which (as the ground was thick with sludge and the victims had fallen down and were rolling about) would be good conductors, and this fact probably accounts for their having survived as long as they did, the wet clothes taking a good deal of the current away from the body. The time-limit appears to have been just under 45 minutes. Several horses were killed at the same time, the wires coming in contact with their heads and death being practically instantaneous. This accident would not have occurred, had the usual guard-wires been fixed above the trolley-wires.

*Accident D.*—A pony was killed by a pressure of 400 volts, in a damp gate-end; vulcanized rubber insulated (single) cables (insulation a good deal worn) were lying on the ground; the pony in being turned round, trod on the cable, and fell down dead. The boy holding the iron shafts did not feel any shock.

There is no evidence in this case as to how the shock was received, that is whether contact was made through two feet and the two cables or only one foot and one cable, in all probability the former. It is natural that the boy should not feel a shock as the harness would be an insulator.

*Accident E.*—A pony was killed at a gate-end by a current of 400 volts. Two single vulcanized cables were securely cleated to the sides of the road. A boy drove the pony to the gate-end, with a journey of empty tubs instead of stopping at the turn-out: this necessitated turning the pony and driving him between the side carrying the cables and the empty tubs. In doing this, the hames caught the cable, the pony struggling to get free cut through the insulation, received a shock, and fell down carrying the cables to the ground. The hames were connected to the girth-band by a chain; the former also being a chain. Endeavours were made to free the pony, but the men received shocks which prevented them from doing so until a messenger was sent to bank to stop the generator, notwithstanding the fact that

there was a double-pole switch within 300 feet of the place where the accident occurred. The pony received the shock for about 15 minutes; it was just alive when the current was shut off, and died shortly afterwards. The only noticeable feature after the accident was that the pony was scorched round the girth.

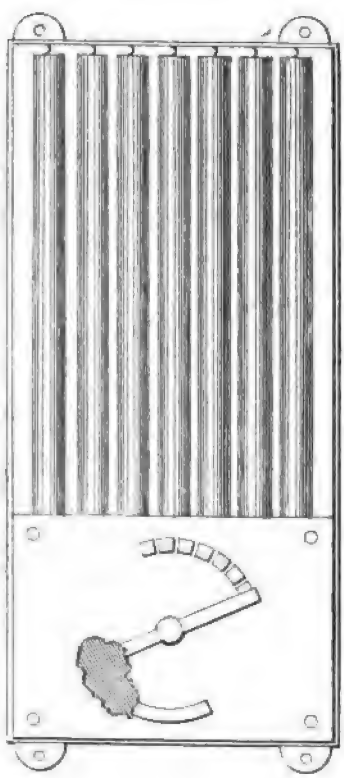

FIG. 4.

In the United States of America, deaths from electricity are more frequent than in this country, on account of the use of bare trolley-wires for the locomotives. In dealing with these cases, continuous currents and a maximum of 500 volts have been chosen. Alternating currents, whether single or multiphase, are at least 50 per cent. more dangerous, both as regards danger to life and fire, and with the exception that some types of motors have no collecting-rings, need not be separately considered.

## ACCIDENTS FROM FIRE.

Accidents from fire are caused by (*a*) short circuits, that is, a positive conductor coming into contact with a negative conductor, causing a heavy rush of current; and (*b*) bad contacts, causing arcing of the current.

*Accident F.*—A small motor was driving a pump, the main switch and the resistance-switch were combined on a slate-base (Fig. 4). The pressure was 500 volts. The lad in the pump-house saw an arc start on the switch at the contact of the movable arm with the metal block: not liking to go near the arc he left the pump to go to the pit-bottom to switch off: and by the time he returned the place was alight. After the fire was extinguished, the switch was found with about 3 inches of brass contact-bar, $\frac{3}{4}$ inch by $\frac{1}{2}$ inch (which was fastened to the slate-base), melted

right away, and the slate in the immediate neighbourhood burnt away nearly ¼ inch deep. The molten metal had fallen on the oily floor, probably oily waste, and as likely as not into a tin jack of oil which was standing below the switch. This fire was due to bad contacts.

The breakage of a cable carrying a current would cause a flash, but experience shews that a fractured cable, if of suitable quality, is unknown, and with almost any quality if erected properly a fracture cannot occur, even with a heavy fall of roof.

A short circuit is rendered harmless by circuit-breakers, that is automatic switches which break the circuit when the current exceeds a predetermined amount; or safety-fuses, which melt and break the circuit when an excessive current passes. For instantaneous action, the former are preferable.

### The Means of Preventing Accidents.

It may be said of electricity, as for steam-, air- or rope-power, that a plant properly designed, erected and maintained, is perfectly safe, except from gross carelessness. This subject requires dividing into three sub-heads:—(*a*) Stationary machinery; (*b*) portable machinery; and (*c*) cables and contact-boxes. Assuming for the present that the design and erection are correct, the question of prevention and maintenance has to be considered.

(*a*) This for stationary machinery is a simple matter, being dealt with as any steam-engine or other machinery, that is, fenced, and no one allowed to do anything (even oiling), whilst it is in motion or with the current on.

What may be termed emergency-switches should be fixed in some position close to, but outside or on the way out of the motor-house, and it should be impossible for these to be accidentally put on, that is to say, the switch should be such that an appreciable effort is required to close it. In stationary machinery, the covering of terminals and the partial or total enclosing of the motors may or may not be a good thing. Personally the author does not recommend it, as totally-enclosed motors are invariably neglected, partly enclosed cannot be got at properly, and as a whole, this covering up leads to a neglect of precautions due to a feeling of security. In most cases, a daily inspection is made, and this is in itself a pre-

vention, provided that defects are reported and steps taken to remedy them.

(*b*) Portable machinery, which practically means coal-cutters, is, from the very nature of the work and surroundings, liable to worse treatment than any other machinery, and should, therefore, be the more scrupulously examined. Probably, the best way, or at all events, one which the author has found to work excellently, is for the machine-man to report after each shift, not only the yardage cut but the condition of the machine when he "comes on," he should also report as to gate-end cables, trailing cables, and gate-end switches.*

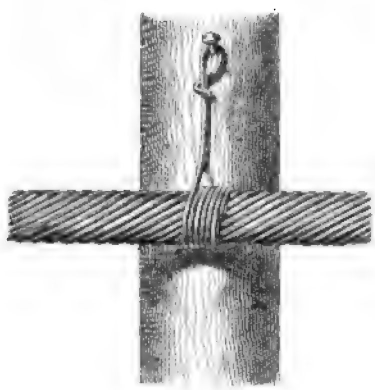
FIG. 5.

The objection to enclosed motors on this class of machine is even greater than in the case of stationary machines, as owing to the extra difficulties of access due to the position, examination and cleaning are neglected, whereas with an open motor the attendant knows that it is dirty and must be cleaned. Terminals and parts carrying current are, of course, protected.

(*c*) Cables on main roads, when once installed, should require no maintenance apart from reinstatement after road-repairs; they should be fixed as shewn in Fig. 5.

In the case of in-bye cables a heavy indictment must be brought against colliery-officials. Cross-gate, gate-road and trailing cables and junction-boxes and switch-boxes are very seldom either erected (after the first start) or maintained in any decent form. It will probably be said that as these positions are all temporary, and liable to troubles from weights, ripping, etc., it is impossible to maintain cables, etc., the same as in main roads. This is so, but engineers being quite conversant with all troubles from these causes, it is an additional reason for paying extra attention to them.

* This is intended for gate-end only, leaving gate-road and other cables to other workpeople.

Take the following case, by no means an isolated one (in fact, it applies to the majority, although there are some cases in which these details receive the most perfect care):—A gate-end with contact-box, main cables on the ground, coils of spare cable, many kinks, two empty tubs turned over sideways on the cable to make room for full tubs passing out; pony turned round at gate-ends treading on cable; men passing in and out by the tubs, walking on the cable; props, rails, sleepers, etc. piled upon cable; contact-box upside down and buried in slack, etc.; trailing cables coiled anywhere, and anyhow, kinked, bare places "insulated" with a strip of brattice, jointed by single strands being twisted, and then hung up away from anything (until something comes in contact with it) by a piece of tarred band.

Compare this with a similar position:—Cast-iron junction-boxes at cross-gate and gate-road junction, gate-road cables slung up (as shewn in Fig. 5) loosely by all means, and in fact, preferably; a few coils of spare cable made up into as large coils as convenient, tied together and placed vertically against the side, and protected by a timber shield or shutter, which carries the gate-end switch or coupling-box; and trailing cables, when not in use and not required, coiled upon a suitable drum.

Further comment is needless, except to say that these positions should be properly maintained, inspected and reported on.

Cables may be of several types (neglecting bare wires):—(*a*) Single, that is two separate cables, both insulated; (*b*) twin, that is two separate cables, both insulated but made up under one cover; (*c*) concentric duplex, that is two cables, both insulated, but one within the other; and (*d*) concentric simplex, that is, one conductor insulated, surrounded by another conductor left bare, the outer conductor being preferably galvanized iron wire. Cables *a*, *b* and *c* are sometimes made up with an armouring on the outside of the insulation.

The large number of materials employed for insulation may be divided into two classes:—(1) Those in which the insulation depends on an outer tube or covering of lead; and (2) those which do not require such a covering. The first class is mechanically and electrically weak, as their life depends solely on the lead, a pin-hole in which will very quickly destroy a long length of cable.

In the second class, the only insulating materials which have stood the test of time are vulcanized rubber and vulcanized bitumen, and these, made up as either *a*, *b*, *c* or *d* types, should be employed.

These various types have each their own advocates. The author advocates type *d*. This class of cable was recommended by him at a meeting of this Institute in 1896, having been designed some years previously, at a time when voltages were increasing to 500, and when the possibility of these accidents with the then existing systems were foreseen. Some of the advantages are:—The very great mechanical strength given by the iron wires; the protection this gives to the insulation: only one cable to run; no insulators required (it is a benefit actually to connect the outer conductor to the rails and pipes); a leakage cannot exist; and it is impossible for a shock to be received by touching the outer conductor.

It has been said that a serious objection to concentric cables is that they cannot be jointed as readily as single cables; this is, however, a fallacy, as temporary joints can be made as quickly in a concentric as in a single cable, and permanent joints can be made easier and better by means of suitable junction-boxes.

Very nearly as important as the class of cable are the position and method of fixing them. They should be placed as much as possible out of the way, and strung up so that they can fall down in the event of a fall of roof (Fig. 5). Trailing cables for coal-cutters have of necessity to be flexible, and should always be wound upon a drum when not in use.

A word of caution may be given as to fuses for 500 volts. The distance between the terminals should not be less than 3½ inches, and they must on no account be mounted on combustible material such as fibre, even though enclosed in an iron box. Several accidents have occurred from this cause.

*Ambulance Work.*—Ambulance-work is very general at collieries, but the method of restoring the apparently drowned or electrocuted might with advantage be made more generally known, and for that reason a description of the Sylvester method is appended, as follows:—

Place the patient on the back, on a flat surface, inclined a little upwards from the feet; raise and support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder-blades. Draw forward the patient's tongue and keep it projecting beyond the lips—an elastic band or piece of string over the tongue and round the chin will hold it in this position. Remove all tight clothing from about the chest and neck, especially the braces.

To imitate the movements of breathing:—Standing at the patient's head, grasp the arms just above the elbows and draw the arms gently and steadily upwards above the head and keep them stretched upwards for two seconds. (By this means air is drawn into the lungs.) Then turn down the patient's arms and press them gently and firmly for two seconds against the sides of the chest. (By this means air is pressed out of the lungs.)

Repeat these movements alternately and deliberately about 15 times in a minute, until spontaneous effort to respire is perceived, immediately upon which cease to imitate the movements of breathing and proceed to induce circulation and warmth.

To promote the circulation:—Rub the limbs upwards with firm grasping pressure, employing handkerchiefs, flannels, etc.

Promote the warmth of the body by the application of hot flannels, bottles or bricks, to the pit of the stomach, arm-pits, between the thighs, and to the soles of the feet.

Allow the air to play freely about the patient, that is, no crowding round him. On the restoration of life, a teaspoonful of warm water should be given, and when the power of swallowing has returned, small quantities of wine, warm brandy and water, or coffee, should be administered. Put the patient to bed, and encourage sleep.

This treatment should be persevered in for some hours, cases are on record of life having been restored after 3 hours' treatment.

Cautions.—Prevent crowding round the patient; avoid rough usage; keep the tongue secured, well forward; under no circumstances hold the body up by the feet; and do not place the body in a warm bath, except by a doctor's order, and then only as a momentary excitant.

The appearances which usually accompany death are:—breathing and the heart's action cease entirely; the eyelids

are generally half-closed; the pupils dilated; the tongue approaches to the under edges of the lips, and these as well as the nostrils are covered with a frothy mucus; and coldness and pallor of surface increase.

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The President (Mr. M. Deacon) said that the members were much indebted to Mr. de Grave for writing his extremely interesting and useful paper, which dealt with a subject of the utmost importance to many mining engineers. The paper had been written with a special object, and it would afford ample material for discussion.

Mr. Wm. Maurice (Tibshelf) said that it was advantageous to hear different expressions of opinion as to the cause of death by electricity. About 18 months ago Dr. R. H. Cunningham published, in the New York *Medical Journal*, an account of a series of experiments carried out to ascertain the mechanism of death by electricity. In brief, that author's conclusions were as follows: —

> When the chest is traversed by a certain number of ampères or fraction of an ampère, for a sufficient length of time, the most important effect produced is the immediate cessation of the co-ordinate beat of the heart; consequently the circulation of the blood throughout the body ceases, and the various delicate nerve-cells of the central nervous system die rapidly from the lack of indispensable blood. The action of the current upon the heart is clearly a physiological one, and the state produced in it is what physiologists term "fibrillation." Roughly speaking, in this condition the rhythmical synchronism of the contractions of the little muscle-bundles of which the heart is composed is profoundly disturbed, and the contractions of the bundles fall out of phase. Thus the heart fails as a blood-pump, and death quickly ensues, unless the circulation is restored. . . . . The higher mammalia practically never recover spontaneously from this condition of fibrillation, but the lower the order of the animal the more likely is it to recover. . . . [He does] not consider that consciousness is lost synchronously with the beginning of the shock, although the period of consciousness may be extremely brief. . . . No reliable data can be given as to the minimum intensity of current necessary to produce cardiac fibrillation in man, adding that probably physiological susceptibility to the current varies. The 110 volts lighting-current seemed capable of electrocuting certain individuals.

All engineers who had much to do with electrical machinery were aware of the widely varying degrees of susceptibility of shock possessed by different people. One person would be acutely affected by a shock from mains carrying a pressure of 100 volts, while another sentenced and submitted to electrocution had (according to the newspapers, be it said) received a shock of 2,000

volts and remained alive. He (Mr. Maurice) had received shocks from mains, at various pressures, from 100 to 500 volts, without other than momentary inconvenience.

In the summer of 1892, he witnessed an accident which forcibly indicated the violent treatment that some constitutions could endure. The electrician to a great mining corporation had climbed upon a roof in order to connect two motor-cables with a pair of mains, which latter were supported (on poles) at a height some 4 feet above the point where he stood. Orders had previously been given to stop the electric supply, but, as events proved, the current was put on again too soon. The electrician in leaning over towards the far cable with which his hands were in contact, accidentally touched with his chin the near main. He was instantly pulled off the roof by the muscular contraction consequent on the shock and momentarily remained suspended in mid-air, with his throat on one main and his hands on the other one. With considerable presence of mind he almost immediately liberated himself, clutched a pole against which he hung, and slid safely down to ground. The only injuries that he received took the form of severe burns (leaving permanent scars) about the hands and throat.

Trifling accidents from fire, caused by arcing of conductors, are of fairly frequent occurrence, though, as Mr. de Grave observed, they would not occur if reasonable care were exercised in the installation and maintenance of electric plant. He had in mind a fitting-shop, which was once nearly set on fire owing to the arcing of a flexible lead. Quite contrary to good electrical practice, a twin flexible conductor was stapled along a roof-rafter, for the purpose of conveying current to a pendant lamp lighting the smith's hearth. Midway between the roof and the lamp was a line of shafting, which almost touched the hanging part of the flexible wire. In course of time, the insulation of this wire at the point near the shaft became saturated with oil, and was, possibly, also more or less abraded. However, the lamp one day fell to the ground, an arc having set up at the point referred to. The insulation was burned away, and the rafter itself was charred before the mishap was discovered. Subsequent investigation showed that the fuse, which should have protected this circuit, had been fitted with a piece of thick copper wire. It is unfortunately a not infrequent practice of a workman when a fuse "blows," to

replace the safeguard with a stout wire. Necessarily a break-down ensues somewhere, sooner or later, through such an act of ignorance or carelessness.

Any revision of Special Rules under the Coal-mines Regulation Acts should include a clause prohibiting unauthorized employés from inserting or removing fuses, or otherwise tampering with fuse- and switch-boxes and automatic protective devices. He mentioned the latter, because some persons had a "little way" of hanging weights upon magnetic cut-outs, as they did with lever safety-valves.

Was it asking too much to suggest that every colliery company should insist upon the whole of its electrical work being installed and maintained in accordance with the safety-provisions of any of the recognized authorities? If this were done, one would cease to hear of little fires, men knocked down, and horses killed.

Mr. de Grave, in the section of his paper devoted to the means of preventing accidents, gave a word of caution as to suitability of fuses for 500 volts circuits. He here touched upon a very important point. Collieries which 12 years ago had 50 to 60 volts dynamos have since replaced them with machines of 200, 300, 500 and sometimes still higher voltages. It is to be feared that in many cases the "change over," as the phrase goes, takes place in the engine-room only. Then, in the weeks following, one would have toy fireworks wherever there was a switch or fuse, due of course to the fact that the old-type fittings were unsuited to the new conditions.

The most serious mine-accident attributable to the electric current that he could call to mind was that which occurred at the K. K. Kaiser Ferdinands-Nordbahn collieries.* In this catastrophe 16 lives were lost. A special commission of enquiry found that the cause of the fire was the rupture of an electric-light conductor and the formation of a continuous arc which ignited the bitumen insulation and their wooden protecting strips. The fire was not extinguished until it had been raging for several hours. It was stated that several lives were lost because the men did not observe the code of directions which had been drawn up for their guidance in the event of such an occurrence.

Mr. G. J. Binns asked how it was that in accident A, with a

* *Annales des Mines*, 1897, vol. xi., page 219.

current of 500 volts, the man on the far side of the switch received 1,500 volts?

The PRESIDENT (Mr. M. Deacon) said that Mr. de Grave declared that an alternating current was 50 per cent. more dangerous than a continuous current. He presumed he meant that the effect upon the human frame of a given number of volts by an alternating current was greater than an equal number of volts by a continuous current. He should like him clearly to explain whether he did not think that the alternating three-phase system was a much safer one than the continuous current for use in mines. He also asked whether Mr. de Grave did not regard the absence of a commutator, and the absence of sparking (which occurred with continuous-current motors, but was absent in the three-phase system) as a great advantage; and also whether the three-phase cables were not considerably safer and less liable through short-circuiting to produce sparking or flashing than cables on the continuous-current system. He also asked whether, in regard to the switches which formed another possible source of danger, Mr. de Grave had had any experience in placing the switches in a bath of oil in an enclosed case. It seemed to him that in considering the adoption of electric power three points required attention:—The possibility of sparking from the cables, from the commutator, and from the switches. But if they could get rid of the difficulty of sparking at the commutator by adopting the alternating current; if they could minimize the cable difficulty by adopting the three-phase system; and if they got rid of the difficulty of the switches by placing them in baths of oil, then to a very large extent they would remove the dangers attendant upon the application of electricity underground. The method of fixing the cables was a matter which deserved very careful consideration. He held a strong opinion that they should be hung as near to the ground as possible, so that the weight of anything falling would not break them, but simply push them to the ground. Where traffic was passing, the cables should be encased in steel or iron tubes or in cast-iron boxes, or where steel-wire armouring was adopted the casing might be dispensed with. He had pleasure in moving a vote of thanks to Mr. de Grave for his valuable paper.

Mr. G. E. COKE, in seconding the resolution, said that the

members owed a debt of gratitude to Mr. de Grave for his able paper on a highly technical subject of very great importance.

Mr. J. H. W. Laverick asked Mr. de Grave whether he could recommend suitable gloves to be worn by colliery-electricians. He had noticed that a French society had been inviting tenders for an international competition for "insulating gloves" to be used by workmen engaged in electrical pursuits, as indiarubber gloves were said not to meet all requirements.*

The resolution was agreed to.

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Mr. H. Pilkington read the following paper on "Blast-furnace Fuels":—

* *Chambers's Journal*, sixth series, 1901, vol. iv., page 142.

# BLAST-FURNACE FUELS.

By HERBERT PILKINGTON.

The large quantity of fuel used in the production of pig-iron in Great Britain alone forms an important part of the product of our coal-mines.

In 1899, 406 blast-furnaces were in operation, and they produced 9,393,018 tons of pig-iron. The coal consumed by these furnaces may be taken at 20,000,000 tons. Practically all of this coal, or its equivalent in coke, actually went into the blast-furnaces, as nearly all the power for operations at blast-furnaces is now generated from the furnace-gases.

The working up of pig-iron into various finished products involves the consumption of even greater quantities of fuel than its production.

Previous to the year 1600, or thereabouts, all iron in this country was made with charcoal as fuel, and several laws of Queen Elizabeth relate to the preservation of the woods and timber, which were suffering very much on this account; and for this reason the production of iron was much curtailed.

About the year 1619, Dud Dudley appears to have first successfully smelted iron with pit-coal, used apparently in the form of coke, at Cradley, in Staffordshire. Dud Dudley received a patent from King James I.; and some years later he petitioned amongst other things, that the laws with regard to timber should be enforced, and what was equally to the point, "to stop all the exportation of pit-coal and sea-coal (paying His Majesty's duty) if the coal be in a fit place to make iron therewith." Dud Dudley was evidently a far-seeing man, but it is over a century later when it is recorded that Darby of Coalbrookdale was successful in using coke instead of charcoal. The use of coke for fuel gradually replaced charcoal, from the time of Darby until the invention of the hot blast in 1830, when the use of raw coal became very general. Anthracite-coal also began to be used in South Wales about the year 1837, and shortly afterwards in the Lehigh valley, Pennsylvania, U.S.A.

The use of non-coking coal and anthracite-coal in blast-furnaces soon assumed very large proportions, but during recent years the use of anthracite has practically ceased in this country, giving place to coke, although anthracite blast-furnaces still flourish in the Lehigh valley.

Charcoal-furnaces, with the exception of about two which still exist, have long ago ceased working in this country, although there are many in America and on the continent of Europe.

In considering the blast-furnace values of fuels, not only are the physical characteristics, such as hardness and density, of importance, but their chemical characteristics are also vastly important.

The duty that fuel performs in a blast-furnace is not alone the production of heat, but its functions are also chemical. Whatever the fuel may be that is in use in a blast-furnace, it is the fixed carbon alone that performs useful duty, all the volatile constituents are driven off as gas, and of course the operation of driving off these volatile matters is accompanied by an absorption of heat. The non-volatile constituents of the fuel, such as ash and sulphur, have to be fused with added lime to form slag, with a heavy expenditure of heat and consequently of fuel.

The ideal fuel for blast-furnaces would be pure solid fixed carbon, but it would even then require to be of a density and crushing strength necessary to descend through the 60 to 80 feet height of furnace, with a gradually increasing temperature, without crushing. It would be requisite also, that it should be so case-hardened that practically all its carbon would arrive at the tuyères, the point of combustion, without loss on the way, and without fusion or cohesion.

Anthracite-coal, in its best form, is perhaps the nearest natural fuel, considering its chemical composition, to this ideal, but mechanically it is not by any means satisfactory. From the table of analyses (Table I.) it will be seen that anthracite may contain from 88 to 94 per cent. of fixed carbon, but owing to the fact that it decrepitates and forms large quantities of dust and fine smalls in the furnace, it very much impedes the action of the gases, and the furnace as a result works very irregularly: the real duty, for instance in South Wales, was such that Rhondda coke was much preferred. In the Lehigh valley, Penn-

sylvania, U.S.A., anthracite has been used with much success, and with outputs of iron rivalling those of our large coke-furnaces: the consumption of anthracite per ton of iron made varying in different works from 23 to 28 hundredweights.

TABLE I.—ANALYSES OF COALS.

| | South Wales. | | South Staffordshire. | | Scotch. |
|---|---|---|---|---|---|
| | Anthracite. | | Thick Coal. | | Splint. |
| | (1) | (2) | (3) | (4) | (5) |
| Moisture ... ... | 0·92 | 1·049 | 3·56 | 4·32 | 11·62 |
| Volatile matter ... | 5·78 | 7·165 | 36·30 | 35·66 | 28·96 |
| Sulphur ... ... | 0·42 | 0·782 | 0·50 | 0·47 | 0·59 |
| Ash ... ... | 3·65 | 3·500 | 2·28 | 2·91 | 5·42 |
| Fixed carbon ... | 89·23 | 87·504 | 57·36 | 56·64 | 53·41 |
| | Derbyshire. | | | | South Yorks. |
| | Hard Coal-seam. | | | | Hards. |
| | (6) | (7) | (8) | (9) | (10) |
| Moisture ... ... | 6·20 | 8·50 | 4·30 | 6·60 | 3·97 |
| Volatile matter ... | 30·10 | 31·12 | 29·22 | 30·25 | 33·90 |
| Sulphur ... ... | 0·58 | 0·69 | 0·57 | 0·74 | 0·52 |
| Ash ... ... | 4·12 | 2·66 | 2·22 | 2·50 | 3·56 |
| Fixed carbon .. | 59·00 | 57·03 | 63·69 | 59·91 | 58·05 |

From an all-round point of view, however, there is no doubt that really first-class coke is the best fuel for blast-furnaces, and it may be taken that the Connellsville coke of Pennsylvania, the Durham, and the Rhondda coke are about the best examples. Really bad coke, of which there are plentiful supplies, is the worst possible fuel for smelting, as will be proved later.

Coking in beehive ovens is certainly not the most economical method of coking, but it undoubtedly produces the best blast-furnace coke, when it is watered in the ovens and drawn by hand.

Furnace-managers, rightly or wrongly, but on the whole rightly, associate improved coke-ovens and mixing arrangements with an increased consumption of coke in the furnaces. A good deal of the extra yield of coke in retort-ovens consists of moisture, and unexpelled or imprisoned hydrocarbons, or at all events of carbon which is not stable or fixed enough to get sufficiently far down a blast-furnace to perform useful work. The percentage content of ash and sulphur in such a retort-oven coke as this, often

appears to be favourably low; if, however, the moisture, the volatile hydrocarbons, and the unstable carbons be driven off, the relation of the ash and sulphur to the fixed solid carbon left does not appear by any means so favourable; indeed, with regard to sulphur, it is often worse than beehive coke. If the same slack were coked, for the sake of illustration, in a gasworks retort and in a beehive oven, or to go to further extremes, in an open coke fire, it may be taken as a certain fact that more sulphur would be driven off in the latter case than in the former.

In the manufacture of cold-blast iron used for special purposes, it is necessary to employ materials of the utmost purity, and in South Staffordshire for this purpose it is the practice to coke the lump coal in open fires with a central chimney. The resulting coke is notorious for its great purity, and the sulphur is often as low as 0·3 per cent.: generally speaking, 70 per cent. of the original sulphur is driven off. Such coke, being made from non-coking coal is very friable and tender, and the quantity made now is very small.

Gas-coke has often been used in blast-furnaces, sometimes in large proportions, but its only virtue is its cheapness; and its softness and friable character result in the production of much dust through crushing. The fixed-carbon percentage in gas-coke is relatively low, and its sulphur is high. As a matter of experience, as against average Derbyshire oven-coke, its use involves a greater consumption of about 16 per cent. in weight.

Coal for use in the blast-furnace should be hard, and of the non-coking variety; it should be free from small, low in sulphur and ash, and high in fixed carbon. The Thick coal of South Staffordshire, the Splint coal of Scotland, and the Top Hards of Derbyshire and Nottinghamshire are probably the three finest varieties, and the last-named is by no means the worst. Coal of semi-coking varieties have at times been used in blast-furnaces, but their use is not very desirable, owing to their tendency to fuse together and become obstructive, and consequently they cause irregularity in the descent of the charge, besides considerable curtailment of output from a given plant.

The use of coal in any case as against coke always means a lesser production of iron in a given time, but very few serious attempts at large outputs, when using coal, have ever been made

in this country, and there is probably a good deal to learn in this direction, particularly in Derbyshire, where the coal is very hard.

In recent times, whenever good hard and reasonably pure coke is obtainable, coal is never used, for instance in Durham and South Wales; but where the coke is inferior and impure, coal is either partly or wholly used, for reasons which will be given later on. It is often the case, however, that financial reasons govern the use of coal as against good coke, for if a ton of iron be smelted at a smaller cost by coal than by coke, in the Midlands, for instance, then more coal will be used and less coke, or *vice versa*, as market values determine. It is nevertheless an important fact that, in the Midland district, for each ton of iron smelted with coal, there is less sulphur and ash introduced into the furnace than if it had been smelted with coke such as the district affords. This fact of itself accounts for a certain economy in fuel-consumption, but also has a very important bearing upon the quality of the pig-iron produced.

It is necessary, in order that a comparison of the blast-furnace values of the various fuels should be arrived at, that their action in the blast-furnace should be considered somewhat more exactly in relation to the duty performed. The interior of a blast-furnace is not only a heating and melting chamber, but it is also a huge chemical laboratory in which complicated reactions take place. It is, however, only necessary to consider such actions in the blast-furnace as may have an immediate application to the subject of this paper. The blast-furnace may be considered as a vertical cylinder in which the diameters at the ends are contracted. The minerals are charged at the upper end, the furnace being kept full continually, and they are tapped at regular intervals in the form of molten iron and slag, at the bottom end. There is, therefore, in the furnace a vertical column of materials. For a few feet at the bottom, these consist of molten iron and slag and incandescent coke; a little higher, of spongy iron in a melting state, and melting slag and incandescent coke; higher still, with a lesser temperature, of spongy iron, holding partly reduced oxide, and earthy matter and lime in process of fusing together to form slag. Above this, there is a considerable height in which the materials as they descend through it, gradually acquire from the ascending gases an increasing temperature. The upper portion

of the furnace is what is termed the reducing zone, and is one also in which the materials are acquiring heat, and in which the volatile constituents are driven off. These zones are of course only approximate, and cannot be sharply defined. The temperature at the top of the furnace seldom exceeds 700° Fahr., and is often much less.

The hot-air blast enters the furnace through the tuyères a few feet from the bottom of the furnace at a pressure of 5 pounds or more per square inch, and the amount blown in per ton of iron made will average 4 to 5 tons. On entering the furnace, the air in the presence of highly incandescent carbon is instantly converted into gas, the oxygen of the air uniting with the carbon of the coke to form carbon monoxide and nitrogen. These gases leave the region of combustion in a highly heated state, and pass rapidly in large volumes up the furnace through the descending materials, permeating every portion of them if the furnace be in good order and free from obstructions. The ascending gases communicate their sensible heat to the materials descending, as they pass through them, until when they emerge from the top of the furnace the temperature in modern furnaces is as low as 500° Fahr.

The nitrogen introduced by the blast, forming about 60 per cent. of the gases generated, is inert in the blast-furnace except for the functions just described of heating the descending materials, and also in the case of hot blast, it carries into the furnace more heat than it takes out at the top, say 1,200° Fahr. on entering and only 600° Fahr. on leaving the furnace.

The carbon monoxide, however, performs very important functions in the upper parts of the blast-furnace, as some 80 per cent. of the work of reducing the iron from the oxide is performed by this gas, ferric oxide ($Fe_2O_3$) being reduced to a lower oxide, and some of the carbon monoxide taking up oxygen and becoming oxidized to carbon dioxide ($CO + O = CO_2$). The oxide remaining in the ore is reduced by solid carbon in the region of combustion, the tuyères. The carbon dioxide formed by the operation of reduction in the upper parts of the furnace is also augmented by the carbon dioxide driven off, in the lower reduction region, from the limestone used as flux. This carbon dioxide in the upper part of the furnace possesses the power of attacking the coke or coal, with which it comes into contact. This action commences at a temperature of about 800° Fahr., and is more

vigorous at higher temperatures, a unit of carbon being absorbed by the carbon dioxide, and the gas becomes carbon monoxide ($CO_2 + C = 2CO$). It is here that the value of good hard silvery beehive-oven coke is proved, because such coke passes through this region with very little loss. The porous black ends of beehive-oven coke are particularly susceptible in this region, and certain porous, soft, black, bye-product coke from retort-ovens suffers in the same way, as also does gas-coke, and indeed, all soft cokes.

When raw coal is used in the blast-furnace this action occurs, but it is doubtful if it is so potent as in the case of coke, owing to the fact that the temperature of the gases leaving the furnace is much lower, particularly in the Midland district.

There are two factors, which lower the temperature of the escaping gases in the furnaces of the Midland district using coal and Oolitic iron-ores:—(1) The duty which the gases perform of expelling the volatile constituents of the coal, and (2) that of expelling the moisture and combined water in the ores.

As a matter of practical experience in Midland blast-furnaces, the amount of fixed carbon used is roughly the same, whether used in the form of coal or coke, although in the case of bad samples of the latter, its requirements of carbon are sometimes in excess of those of coal.

The mechanical condition of the fuel has an important bearing upon the efficiency with which the gases perform their duties. If the fuel be not hard enough to bear rough handling in unloading and charging, and the crushing weight of the materials in the furnace, the result is the production of much smalls and dust. Fuel-dust in serious quantities is a great evil, and with anthracite-coal and some kinds of soft coal, it has such results that at times the blast cannot penetrate into the furnace. Soft weak coke produces dust in large quantities, not such as anthracite, but in quantities sufficient to cause much trouble and loss. The dust, so formed, prevents the regular action of the furnace-gases (which has just been described), and enables much of the material to escape their action, so that portions of ore frequently arrive at the tuyères imperfectly reduced, and not prepared as they should be for fusion. When the gases are deflected by dust, in their ascent through the furnace, the result is sometimes also the formation of

obstructions known as "scaffolds," which build up and impede the downward travel of the materials. All these irregularities require an expenditure of extra fuel to counteract the loss of temperature which they bring about.

Experience with such fuels as gas-coke and certain forms of soft retort-oven coke has shown that, with about equal ash and sulphur, the difference in consumption per ton of iron, owing to the mechanical strength and structure of the coke, may amount to as much as 4 to 5 hundredweights per ton, taken over long periods. Apart, however, from the question of waste of fuel, is the serious matter of the quality of the iron, which is always very much deteriorated by these irregularities and consequent extremes of temperature.

The importance of purity in blast-furnace fuels is such, that no coke ought to be used unless it be made from washed slack, and the day is fast approaching when this practice will be universal.

Nearly the whole of the sulphur introduced into the furnace enters into the slag and iron, in the proportion of about 96 per cent. in the slag and 3 to 4 per cent. in the iron. The presence of sulphur in iron is very objectionable, causing red-shortness, and also closing the grain, so that foundry-irons cannot be successfully produced if the iron absorbs as much as 0·1 per cent. of this metalloid. Much excess lime is used to absorb sulphur when there is more than a normal quantity present, and even then, any fall of temperature in the hearth will cause the iron to absorb more than usual.

The ash in coke, like other impurities, by its presence merely robs the furnace of so much carbon in each ton of coke charged, and like sulphur requires fusing and fluxing with lime; but it has also a deleterious effect upon the iron. Owing to the fact that the coke goes right down to the tuyères to be burnt, and the ash of course with it, the silica of the ash is reduced to silicon in the presence of molten iron in the hottest part of the furnace, and consequently all fuels containing large quantities of ash are as a rule responsible for higher silicon in the pig-iron than if the ash were normal. The same amount of silica in an ore is not nearly so troublesome to deal with, as it is fluxed off earlier and more readily in the furnace. Silicon above a certain percentage is very

objectionable in pig-iron, as it very greatly reduces its strength, and is a source of waste in many subsequent manipulations.

Moisture and volatile matter, as pointed out previously, also supplant a certain amount of fixed carbon in coke, and although they do not provide any slag-making material, they absorb in some cases much heat for their expulsion, although in the case of coal-fed furnaces the volatile gases no doubt provide as much heat as serves for their own expulsion.

The extra consumption of fuel caused by the solid impurities, sulphur and ash, is a very serious item, and although it varies with the character of the ash and coke in different districts, experience shows definitely the value of clean washed coke. A furnace, with the same ore in both cases, was worked a length of time upon the best coke obtainable, the ash being about 7 per cent., and the sulphur about 0·9 per cent.; with this fuel it did its work with a coke-consumption of about 21 hundredweights per ton of iron. The same furnace was afterwards worked upon a coke containing 16½ per cent. of ash and 2 per cent. of sulphur: the coke-consumption increased to 26 or 27½ hundredweights per ton of iron, and the iron was of lower quality than that produced in the former case, although an excess of lime was used.

When raw coal is used, the amount of ash and sulphur introduced into the furnace is very low compared with ordinary coke. In the furnace just referred to, it would have required less than 2 tons of coal to produce a ton of iron.

A reference to Table II. of analyses will show that the ash and sulphur introduced would be about the same as with the best coke obtainable; therefore, as against poor coke, coal has many advantages:—(1) Better iron is made, with less sulphur and silicon in it; (2) much less limestone is required, and consequently, much less slag is made; and (3) having less limestone and therefore less slag to melt, the equivalent economy in weight of coal as against poor coke is great. Coal cannot, however, be pitted against first-class coke.

A word may be said with respect to the efficiency of the heat-duty performed in a blast-furnace. An unit of coke, deducting 10 per cent. of impurities, burnt to carbon dioxide ($CO_2$), may be said to develop 7,200 calories, and the blast-furnace can show that it usefully employs 3,960 calories, or 55 per cent. when

TABLE II.—ANALYSES OF COKE.

| | Rhondda. | | | | Connellsville, Pennsylvania. | | Durham. | | South Yorkshire. |
|---|---|---|---|---|---|---|---|---|---|
| | No. 3. | | Mixed Slack-coal. | Mixed.* | | | | | Unwashed. |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Moisture ... | 0·65 | 0·54 | 0·50 | 1·82 | 0·037 | 0·036 | 0·40 | 0·75 | 3·07 |
| Volatile matter ... | — | 0·75 | 1·20 | 3 19 | 0·530 | 0·535 | 1·52 | 0·85 | 6·10 |
| Sulphur ... | 0·79 | 0·80 | 1·00 | 0·97 | 0·636 | 0·877 | | 0·90 | 1·64 |
| Phosphorus ... | — | 0·02 | — | — | 0·008 | 0·010 | 6·86 | — | — |
| Ash ... | 6·80 | 6·78 | 12·80 | 9·86 | 9·056 | 9·183 | | 8·10 | 17·56 |
| Fixed carbon ... | 91·76 | 91·11 | 84·50 | 84·16 | 89·733 | 89·359 | 91·22 | 89·40 | 71·63 |

| | South Yorkshire. | | | | | | | North Staffordshire. | |
|---|---|---|---|---|---|---|---|---|---|
| | Unwashed. | | Washed. | | | Bye-product Ovens. | | Washed. | |
| | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18)† |
| Moisture ... | 5·64 | 9·48 | 1·68 | 0·92 | 1·10 | 7·80 | 9·53 | 1·25 | 6·25 |
| Volatile matter ... | 5·96 | 4·68 | 2·30 | 2·60 | 2·80 | 10·77 | 6·96 | 1·32 | 7·10 |
| Sulphur ... | 1·74 | 2·09 | 1·47 | 1·50 | 1·68 | 1·46 | 1·72 | 1·56 | 1·38 |
| Phosphorus ... | — | — | — | — | — | — | — | — | — |
| Ash ... | 17·86 | 18·19 | 11·05 | 10·75 | 11·72 | 12·65 | 13·50 | 9·95 | 10·99 |
| Fixed carbon ... | 68·80 | 65·56 | 83·50 | 84·23 | 82·70 | 67·32 | 68·29 | 85·92 | 74·28 |

| | Derbyshire. | | | | | South Staffordshire. | | Gas Coke. | |
|---|---|---|---|---|---|---|---|---|---|
| | Washed. | | | | Picked Hards. | Thick Coal Coke. | | | |
| | (19) | (20)‡ | (21) | (22) | (23)§ | (24)‖ | (25)‖ | (26) | (27) |
| Moisture ... | 1·83 | 9·52 | 3·35 | 1·31 | 0·42 | — | Trace | 14·90 | 10·83 |
| Volatile matter ... | 5·41 | 2·89 | 2·77 | 2·01 | 1·20 | — | Trace | 4·63 | 2·72 |
| Sulphur ... | 1·89 | 1·21 | 1·75 | 1·30 | 0·57 | 0·39 | 0·40 | 1·94 | 1·23 |
| Phosphorus ... | — | — | — | — | — | — | — | — | — |
| Ash ... | 13·50 | 9·89 | 13·95 | 11·05 | 6·88 | 4·50 | 3·78 | 10·84 | 10·88 |
| Fixed carbon ... | 77·37 | 76·49 | 78·18 | 84·33 | 90·93 | — | 95·82 | 67·69 | 74·34 |

* Coppée Coke-ovens. † Bye-product Ovens. ‡ Watered outside. § Coked in beehive-ovens. ‖ Open fires.

worked with heated blast. Added to this, another 15 per cent. or more of duty is derived from the gases generating the power required for performing the operations at blast-furnaces. Therefore, the combined heat-duty of a modern blast-furnace plant can be placed at 70 per cent. efficiency, a duty which cannot be approached by any other form of heat-apparatus.

Recent developments in the direction of the use of blast-furnace gas for power-production by means of gas-engines are likely to increase very much the useful duty performed by fuel in blast-furnaces. Furnaces using coal may be said to produce about 260,000 cubic feet ot gas per ton of iron made, while furnaces using coke produce about 200,000 cubic feet per ton of iron. Experience has proved that 85 cubic feet of gas from a coal-fed furnace, or 125 cubic feet from a coke-fed furnace, will produce 1 indicated horsepower in a gas-engine.

About one-third of the gases produced are used in heating the blast, and in some cases with dilapidated iron-pipe stoves more than one-third is used. The remaining two-thirds partly escapes into the atmosphere and partly is employed in steam-raising. Engines and boilers at blast-furnaces are not usually celebrated for economy, and in some plants using coke nearly the whole of the gas is required for steam-raising and heating the blast. Where coal is used there is always plenty of surplus gas, when it is properly collected by means of closed tops, as is now always done in modern plants. In coke-fed furnaces, where economical engines and boilers are used, there is always some surplus escaping gas.

The amount of gas used under steam-boilers to produce 1 indicated horsepower is about four times as much as when used in a gas-engine.

It would be no exaggeration to say that it is only a question of time before steam-boilers and engines at blast-furnaces become obsolete, and that blast-furnaces will, by the practice of economy in the use of gas for their own purposes, be in a position to supply enormous quantities of power for other purposes. By means of electrical distribution such power could be supplied at considerable distances away. One enthusiast has gone so far as to prophesy that blast-furnaces will become simply vast producers of gas and therefore power, and that pig-iron will

become a bye-product. Such a dream is not likely to be realized, but some such developments will in part become an accomplished fact, and may enable British blast-furnaces to withstand the competition of countries where the natural resources are much greater.

The PRESIDENT (Mr. M. Deacon) said that the last paragraph in the paper had raised a smile, but some of the members would be surprised to learn that pig-iron was at the present time a bye-product, and that slag was the profitable part of the production. And if slag was now valuable, why should not gas be of value in the future? He had pleasure in moving a hearty vote of thanks to Mr. Pilkington for his paper.

Mr. A. CHAMBERS seconded the resolution, which was cordially approved.

# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
MARCH, 16TH, 1901.

MR. T. V. SIMPSON IN THE CHAIR.

Mr. R. W. GLASS read the following description of "Endless-rope Haulage at Axwell Park Colliery":—

## ENDLESS-ROPE HAULAGE AT AXWELL PARK COLLIERY.

BY R. W. GLASS.

Axwell Park colliery is situated near Swalwell station on the Newcastle and Blackhill railway. The Five-quarter and Stone coal-seams are worked by means of a drift. The output is about 90 scores of tubs per day of 10 hours. This quantity is hauled along a single main-road, with irregular gradients (Fig. 1, Plate VII.), by means of steam-engines placed on the surface.

The engine-house, a brick building (Fig. 2, Plate VII.) situated between the heapstead and the drift-mouth, is placed parallel with and adjoining to the engine-plane. It contains two engines of the locomotive type, one being kept as a spare engine in case of break-downs, etc. The hauling-engines stand side by side and are numbered Nos. 1 and 2 respectively. No. 1 hauling-engine is a high-pressure engine with two cylinders, 16 inches in diameter and 24 inches stroke. The crank-shaft, $6\frac{3}{4}$ inches in diameter, carries a belt-wheel, 8 feet in diameter. The boiler is worked at a pressure of 70 pounds per square inch, and only consumes 30 hundredweights of coal per day. No. 2 hauling-engine is compound, with a high-pressure cylinder 10 inches in diameter, a low-pressure cylinder $17\frac{1}{2}$ inches in diameter, and the stroke is 18 inches. The diameters of the crank-shaft and belt-wheel, and the steam-pressure, are the same as for No. 1 hauling-engine, but the consumption of coal is only 24 hundredweights per day. The hauling-engines are connected with the gearing: No. 1 by means

of a sliding pinion-wheel, and No. 2 by a tusk-clutch. The power of either engine is transmitted to the first-motion shaft of the gearing, by means of belts, 12 inches wide and seven-ply thick. The belt-pulleys on this shaft are each 7 feet in diameter. The distance between the crank-shafts of the engines and the first-motion shaft of the gearing is 36 feet. The spur-wheel and pinion-wheel are of cast-iron, 7 inches wide and 2½ inches pitch; and the rope is driven by a Fowler clip-wheel, *A*, 8 feet in diameter. The ratio of the revolutions of the hauling-engine to those of the driving-wheel are as 9 to 1.

The section of the haulage-road from the heapstead to the innermost landing is irregular, the maximum gradient against the load being 1 in 12, and the maximum gradient in favour of the load 1 in 24 (Fig. 1, Plate VII.).

*Ropes.*—The main rope, 11,100 feet long and 2½ inches in circumference, is made of crucible steel, with a steel core and Lang lay; there are six strands, each containing six wires, and the rope weighs 6 tons 5 cwts. 3 qrs.

The rope on leaving the driving-wheel, *A*, passes over a vertical pulley, *B*, fixed on the floor of the heapstead, thence down a staple, where it passes around a vertical pulley, *C*, sliding between guides, and thence upward to another vertical pulley, *D*, which is also fixed to the floor of the heapstead (Figs. 3, 4 and 5, Plate VII.). These wheels form a rope-tightening arrangement, and take up the slack of the off-coming rope. These pulleys are all 6 feet in diameter.

The rope next passes about half-way round a pulley, *E*, 11 feet in diameter, set in a horizontal frame fixed to the heapstead, and in a line with the centre of the empty-tubs road; it next passes over a carrying sheave, *c*, 24 inches in diameter, and is then brought down and passed under a sheave, *d*, 24 inches in diameter, fixed high enough above the rails so as to allow a tub, with a clip attached, to pass underneath it (Fig. 6, Plate VII.).

The arrangement shown in Figs. 7 and 8 or 9, 10 and 11 (Plate VII.) is adopted for binding the rope into position, at all places where tubs are detached from the haulage-rope.

The rope is then taken inbye and passes 2½ times round the terminal wheel, *K*, at the third landing, thence to a tension-wheel, *H*, which is fixed on a moveable bogey and its position adjusted by

a screw (Figs. 16 and 17, Plate VIII.); thence the rope passes outbye to the surface, where it passes round a pulley, *J*, 11 feet in diameter, to the driving-wheel, *A*, in the engine-house (Fig. 2, Plate VII.).

At the third landing, the terminal wheel, *K*, drives two wheels keyed upon the same shaft:—one wheel is used for hauling coals from the east district, and the other from the cross-cut and west districts. These wheels are 6 feet in diameter, and are of the fleeting type. The east district rope is of the same quality and construction as the main rope, and the arrangements for attaching and detaching tubs to and from the rope are similar to those employed on the main road. The cross-cut and west districts rope is 7,800 feet long; it is similar in construction to the other two ropes, and weighs 4 tons 14 cwts. 1 qr. This rope is driven by a fleeting pulley keyed to the shaft of the main return-wheel, *K*. The rope is passed 1½ times around this wheel, it is then taken inbye for a length of 1,100 feet, it thence passes round a pulley (6 feet in diameter) which conducts it westward for a distance of 1,500 feet. The rope is then passed round a return pulley, 6 feet in diameter, and brought outbye to the main road. The rope then passes round another pulley (6 feet in diameter), which conducts it to the face of the cross-cut district, where it passes round a return pulley, and thence outbye to the third landing, a distance cf 4,800 feet.

*Landings.*—There are two intermediate landings on the main road, the first being 3,000 feet (Figs. 12 and 13, Plate VII.) and the second 4,500 feet (Figs. 14 and 15, Plate VII.) from the drift-mouth. At the first landing, the full tubs are detached and part of them sent to the Whickham pit, but the empty tubs run through (Figs. 12 and 13, Plate VII.).

At the second landing, the coals from the Stone coal-seam are attached. The drift, driven from the Five-quarter into the Stone coal-seam, rises 1 in 6, and is worked by a self-acting endless rope. At this landing, the empty tubs are detached from the rope; and the full-tubs rope is suspended by means of a hanging-pulley, *L*, while the full tubs are being attached (Figs. 14 and 15, Plate VII.).

The third landing, the largest in the pit, is supplied with coals from the cross-cut and west districts, from the east district by a branch rope, from the west district by an incline, and from the

Stone coal-seam by a drop-staple. The empty tubs on leaving the rope, gravitate and cross the full-tubs road (by means of a bridge, *M*, (Figs. 16 and 18, Plate VIII.) from the drop-staple and west districts; the empty tubs required for the staple and west districts are switched round the turn into a siding, *N*, those for the east district are similarly treated, and those for the cross-cut and west districts proceed straight forward (Fig. 16, Plate VIII.).

On the cross-cut and west districts engine-plane there are two intermediate landings and also landings at the return-wheels in each district.

In the east district, there is a landing at the return-wheel.

All the kips at the landings have a fall of 1 inch per yard.

An automatic knock-off, *O*, is fixed at each landing, etc., for detaching the tubs. It consists of two sheaves, *a* and *b*, 8 inches in diameter, fixed between two runners of wood or iron, about 15 feet long. The rope passes under one of the sheaves and over the other, and when a tub, carrying a clip, passes underneath it, the rope leaves the clip and passes through the knock-off (Figs. 7 and 8 or 9, 10 and 11, Plate VII.).

The rope-binding arrangement, *P*, consists of two sheaves, *c* and *d*, 14 inches in diameter; the rope passes over one of them and under the other wheel, which is placed high enough above the rails to allow a tub with a clip attached, to pass below it, and to be attached to the rope. The arrangement is generally termed a "hanging-on wheel" (Fig. 6, Plate VII.). All the tubs must pass under a hanging-on wheel, so that they may be attached to the rope.

An automatic binding-down wheel is used for keeping the rope down in "swalleys." It consists of two lengths of rails, *a* and *b*, fastened and supported at the joint by a bar, *c*, to which are bolted two rods, *d*, one at each side of the rails. The rods, *d*, are bolted to the arms, *e*, which are keyed upon the shaft, *f*, as are also the arms, *g*, which carry the sheave, *s*, and the weight, *w*. The action of the machine is as follows:—The weight of the tub forces down the rails, *a* and *b*, hung upon the short lever, *c*, which operates the long lever, *g*, lifting the sheave, *s*, and allows the tubs to pass under it (Figs. 19, 20 and 21, Plate VIII.).

*Haulage-clips.*—The Rutherford-Thompson haulage-clip is used throughout the pit. It is an ingenious appliance, and is

readily attached to a tub (Figs. 22 and 23, Plate VIII.). Detailed views of the rope-gripping apparatus are represented in Figs. 24, 25, 26 and 27 (Plate VIII.). The clip is composed of two oscillating forks, $y$, $y^1$, mounted on pins and geared by a few teeth or coupled together by means of a link (Figs. 26 and 27, Plate VIII.). This apparatus is automatic, and when a tub carrying the clip is conducted into the plane of the haulage-rope, the motion of the latter through the forks of the clip causes them to close upon the rope, by frictional contact, and to grip it firmly. The grip is proportionate to the weight of the tub, and it thereby reduces the damage to the rope by gripping to a minimum. This appliance allows the tubs to be hauled centrally, and reduces the friction and the liability of the tubs to leave the rails. Another form of this clip is shown in Figs. 28, 29 and 30 (Plate VIII.).

*Tubs.*—The tubs are also fitted with Rutherford-Thompson lubricators and pedestals, *x*, *x*, (Figs. 22 and 23, Plate VIII.) which save about 50 per cent. of the grease used in the ordinary method of greasing tubs. In a comparative test, a tub greased by hand consumed 4·084 pounds per tub per 11 working days, whereas a tub fitted with Rutherford-Thompson lubricators only consumed 1·875 pounds under similar conditions, a saving of 54 per cent.

The tubs are coupled in pairs to the haulage-rope, about 120 feet apart; the first tub carries a clip at each end, and the second tub is coupled to the first tub by means of a short chain.

*Automatic Tub-attacher.*—The Rutherford-Thompson clip enables curves and junctions to be worked automatically, thus saving the cost of attendants; the tubs detach themselves from the rope by means of the knock-off, *O*, and gravitate down the kip, gaining sufficient speed to run them into the machine, *P*, which attaches them to the rope automatically (by the weight of the tubs). This appliance (Fig. 31, Plate VIII.) consists of two lengths of rails, *a* and *b*, fastened together and supported at the joint by a bar, *c*, to which are bolted two rods, *d*, one at each side of the rails. The rods, *d*, are bolted to two bell-cranks, *e*, which are fitted on the shaft, *f*; to this shaft, two weighted arms, *w*, are fitted. The quadrants, *e*, are bolted to the bars, *g*, which controls the arms, *h*, fixed upon the shaft, *i*, as are also the arms, *k*, carrying the sheave, *s*, which is held in position by catches, *l*, fixed on the arms, *k*, and on

the rods, *m*. The rods, *m*, rest on the quadrant, *n*, which lifts the (bars) rods, *m*, releasing the sheave, *s*, when tubs pass under it. The action of the machine is as follows:—The tubs lift the quadrant, *n*, which lifts the rods, *m*, and releases the sheave, *s*, so as to allow the tubs to pass under it. After the tubs have passed beyond the wheel, *s*, the rails are forced down, and operate the bell-cranks, *e*, the bars, *g*, the arms, *h*, and the sheave, *s*, which forces the rope into the clip. This arrangement is fitted in a wooden frame, securely fastened to the top and bottom of the seam. Two of these machines have been in use at South Derwent colliery for over 15 years, and have given the greatest satisfaction.

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Mr. T. V. Simpson asked whether the ropes were damaged by the Fowler driving-pulley. He thought that the Rutherford-Thompson haulage-clip was a good one, as the rope was not deflected, and it could not damage the rope.

Mr. N. M. Thornton asked for information as to the cost of repairing the haulage-clips.

Mr. F. Davison said that one Rutherford-Thompson haulage-clip could bring out 12 or 14 tubs, but on heavy inclines (5 to 18 inches per yard) it was desirable to use a clip at both ends of the descending full tub, in order to prevent the tub being damaged. One clip was sufficient, placed at the rear end of a full tub, when ascending an incline.

Mr. H. S. Stratton asked whether both clips were acting, when two were attached to one tub.

Mr. R. W. Glass, replying to the discussion said that, if the Fowler driving-pulley was not kept properly adjusted, it tended to injure the rope. One rope had been in use for about 8 years, and was then taken off, because the district was abandoned. The haulage-clips should be re-adjusted about once a month, otherwise they became slack, and the rope surged through and speedily wore away the sides; if the clips wore at one side it was due to the steel being too soft. One blacksmith could easily keep 750 clips in repair. The road should be raised, or binding-down sheaves inserted at points where the tubs were below the line of the rope, otherwise the clips would be detached from the tubs.

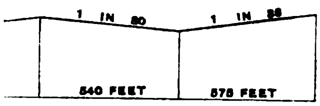
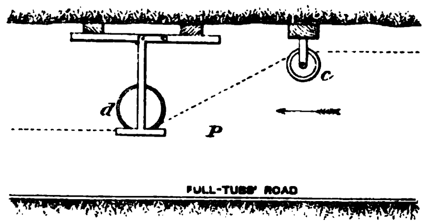
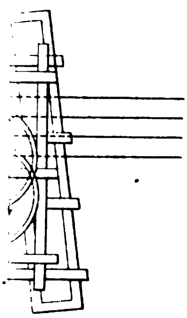



Fig. 6.—Section of Hanging-on Wheel.




Scale, 10 Feet to 1 Inch.



... Feet to 1 Inch.

Automatic Tub-detachers.

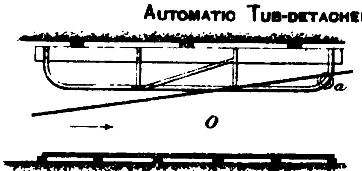



Fig. 7.


Fig. 8.

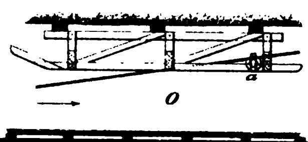



Fig. 9.

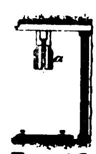



Fig. 10.


Fig. 11.

Scale, 10 Feet to 1 Inch.

Second Landing.

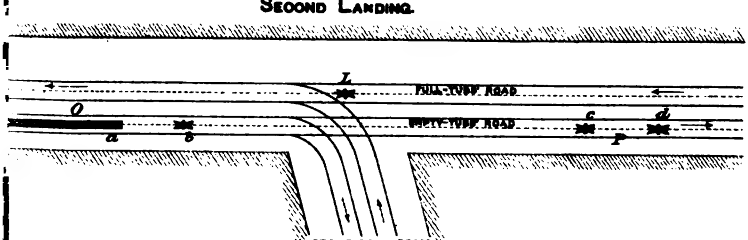



Fig. 14.—Plan.

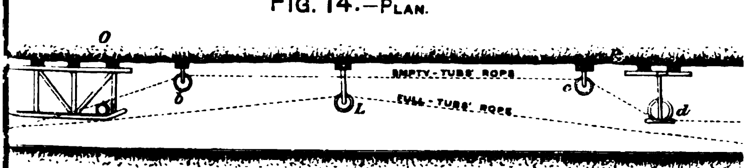
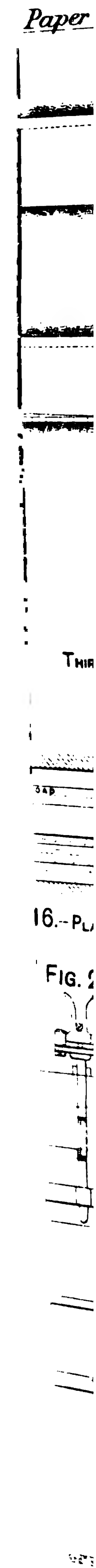
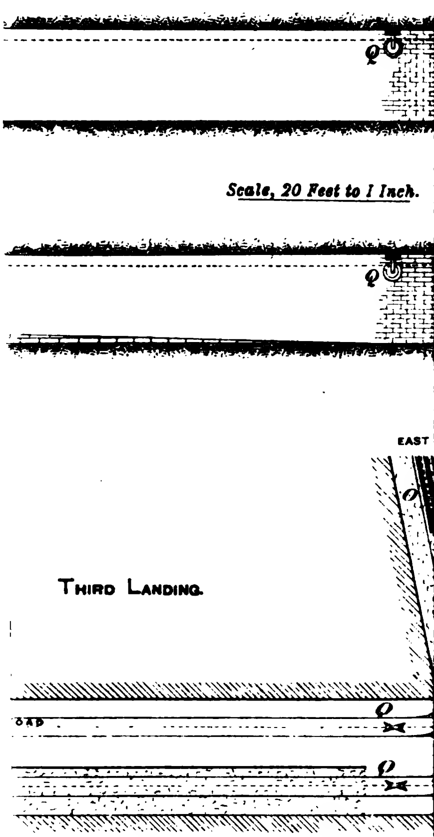



Fig. 15.—Section.

Scale, 20 Feet to 1 Inch.


Paper

Haulage-clips.




16.—Plan.

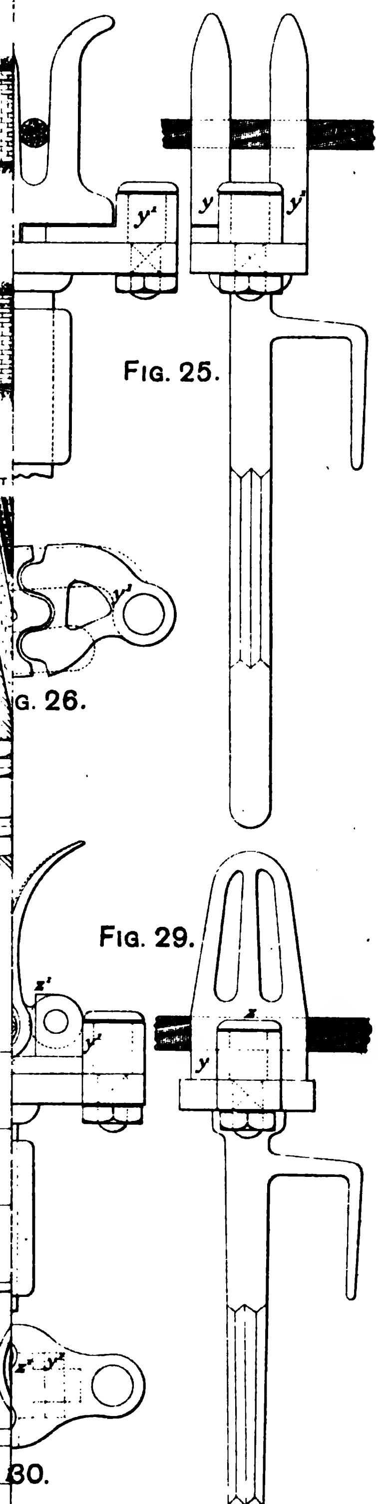
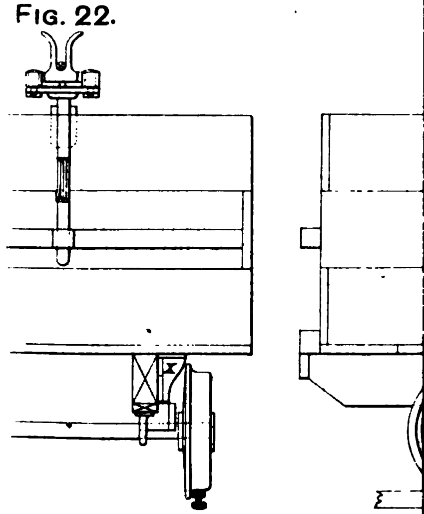



Fig. 25.

G. 26.

Fig. 29.

Fig. 22.




*Scale, 2 Feet to 1* 30.

*es to 1 Inch.*

And^w Reid & Comp^y L^td Newcastle on Tyne

The rope is readily inserted between the forks of the clip, no force being required. Both clips, when two are attached to one tub, act together, if properly forked, as they both have exactly the same amount of pitch or oscillation, and consequently they both move equally in the same direction, when they are attached to the rope. Ordinary tub-grease was used, costing 4s. per hundredweight, in the test of the lubricator, and the hand-greased tub used 4·084 pounds during 11 working days, while the tub fitted with Rutherford-Thompson lubricators only used 1·875 pounds in the same period, a saving of 54 per cent.

A cordial vote of thanks was accorded to Mr. Glass for his paper.

# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

## GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, APRIL 13TH, 1901.

MR. J. G. WEEKS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the Minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on March 30th and that day.

## AWARDS FOR PAPERS.

The SECRETARY read the following list of papers, communicated during the year 1899-1900, for which prizes of books had been awarded by the Council to the authors:—

"The Driving of a Stone Drift at the West Wylam Collieries." By Mr. Sidney Bates.

"The Kalgoorlie Gold-field." By Mr. S. J. Becher.

"Description of Present and Proposed Methods of Operating Vinton No. 3 Colliery, Vintondale, Pennsylvania, U.S.A. By Mr. C R. Claghorn.

"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse.

"Automatic Sprayer for Preventing Accumulations of Dust in Mines.' By Mr. R. Harle.

"The Coal-fields of Natal." By Mr. W. T. Heslop.

"Ore-deposits of Mount Lyell, Tasmania." By Mr. J. J. Muir.

"The Mineral Resources of Tasmania." By Mr. J. J. Sandeman.

"Longwall Methods in the Eastwood District, Nottinghamshire." By Mr. N. M. Thornton, Student.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. ERNEST J. BAYLISS, Civil and Mining Engineer, Elvina, Studland Road, Bournemouth; and 6, Plaza Orense, Corunna, Spain.

Mr. THOMAS HENDERSON BLAIKLOCK, Colliery Manager, Allhallows Colliery, Mealsgate, *via* Wigton, Cumberland.

Mr. Robert William Barrow Elsdon, Civil Engineer, c/o Messrs. Henry S. King and Company, 65, Cornhill, London, E.C.

Mr. David Harris, Mining and Civil Engineer, Elandslaagte, Natal, South Africa.

Mr. Joseph Hassall, Mine Manager, Abbey Villa, Treqrehan Place, Kenilworth, near Cape Town, South Africa.

Mr. Tom Alfred Lishman, Colliery Manager, Harton Colliery, Tyne Dock, South Shields.

Mr. John Livesey, Colliery Manager, Rose Hill Colliery, Bolton, Lancashire.

Mr. Nicholas Samwell, Mining Engineer, Denuki Bay, near Soemalata, North Celebes, Dutch East Indies.

Mr. Augustin Trigo de Serrano, Mining Engineer, 30, Beverley Road, Anerley, London; and Cabrales, Provincia de Oviedo, Spain.

Mr. Sydney A. R. Skertchley, Mining Engineer, 27, Rutland Park, Willesden Green, London, N.W.

Mr. James Wilson, Colliery Manager, Wellington House, Edmondsley, Chester-le-Street, County Durham.

Associate Members—

Mr. Alfred Atkinson, Exchange, Middlesbrough-upon-Tees.

Mr. William Spence Haswell, 47, Esplanade, Whitley, R.S.O., Northumberland.

Mr. Peter Joseph Macleod, Coromandel School of Mines, Coromandel, Auckland, New Zealand.

Mr. J. Montagu E. S. Tharp, 44, Harcourt Terrace, London, S.W.

Associates—

Mr. John E. O'Keefe, Deputy, Linton Colliery, Morpeth, Northumberland.

Mr. Richard Robinson, Miner, Bell's Cottage, Broughton Moor, near Maryport, Cumberland.

Students—

Mr. Nathaniel J. Clark, Mining Student, 1, Hawthorn Terrace, Pelton Fell, Chester-le-Street, County Durham.

Mr. William H. Gidney, Mining Student, Hebburn Colliery, Hebburn, County Durham.

Mr. Charles Arthur Pattison, Mining Apprentice, 16, Stanhope Road North, Darlington.

Mr. Edward Heton Roberton, Mining Student, Seaton Delaval Colliery, Newcastle-upon-Tyne.

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The Rev. H. Palin Gurney, Principal of the Durham College of Science, read the following "Memoir of the late Lord Armstrong":—

# MEMOIR OF THE LATE LORD ARMSTRONG.

By Principal H. PALIN GURNEY.

William George Armstrong, the first and last Baron Armstrong of Cragside, was born on November 26th, 1810, at No. 6—now No. 9—Pleasant Row, Shieldfield, Newcastle-upon-Tyne. His father, Alderman William Armstrong, came from Wreay, a village near Carlisle. He was mayor of Newcastle-upon-Tyne in 1850, and filled the responsible position of chairman of the River Tyne Committee of the Newcastle corporation from 1843, till it was merged in the River Tyne Commission, of which he continued a member till his death in 1857. His mother, Mrs. Ann Armstrong, was the daughter of Mr. William Potter of Walbottle House. She was a lady of considerable literary culture, and her amiable and gracious disposition, caused her to be beloved by all who knew her. Lord Armstrong always spoke of his mother with deep affection, and the almshouses, which he built at Rothbury, are dedicated to her memory.

Alderman Armstrong was a well-educated man, noteworthy as a good mathematician, who contributed to the diaries, and collected a valuable mathematical library, which his son gave to the Literary and Philosophical Society of Newcastle-upon-Tyne. Alderman Armstrong was one of the earliest supporters of that institution, and he was also one of the original members of the Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne.

During the childhood of Lord Armstrong, a slight constitutional delicacy confined him for long intervals to the house. He had no playmates, his only sister being older than himself, but his loneliness only served to foster his natural genius and to make him more self-reliant and resourceful. He took great pleasure in mechanical toys, but they were invariably taken to pieces to find out how they acted. A favourite amusement was to construct machinery out of old spinning-wheels and house-

hold articles. When these were set in motion by weights hung by strings over the rail of the stairhead he played at grinding corn, pumping water, or other useful work. He spent many happy hours in the shop of a joiner, who worked for his grandfather, where he familiarized himself with tools, and imitated the jobs of his humble friend.

Lord Armstrong was at first placed at a private school in Newcastle. He was afterwards sent to Whickham, and subsequently, in 1826, to the Grammar School at Bishop Auckland. The engineering works of Mr. Ramshaw were near this town; and in 1834, Lord Armstrong married Mr. Ramshaw's daughter Margaret, a lady of great force of character, who ably and heartily seconded the philanthropic schemes of her husband. She was Mayoress in 1850; and in 1893 she died, without issue, and was buried at Rothbury.

In 1828, Lord Armstrong was articled to Mr. Armorer Donkin, a highly respected solicitor of Newcastle-upon-Tyne. He then completed his legal education in the chambers of his brother-in-law, Mr. Watson, afterwards a Baron of the Exchequer. In 1833, he was admitted to a partnership in the firm, which was then styled "Donkin, Stable and Armstrong."

But Lord Armstrong's heart was always set upon engineering. He spent many hours of his leisure watching the machinery in the High Bridge Works, and he took the greatest interest in all mechanical operations. In 1835, his attention was attracted to the waste of energy in an overshot water-wheel, which supplied power for a quarry in Dent Dale, Yorkshire. For three years, he considered the best method of utilizing the force of a stream, and in 1838 he published his ideas on the use of water as a motive power in the *Mechanics' Magazine*. He was never content to throw out suggestions, and to leave to others the task of overcoming the difficulties of their practical application. In 1840, he described in the same periodical a water-pressure wheel, which he had constructed, and which was a great improvement on any in use up to that time. The circumference of the wheel was fitted with equal circular discs, whose diameters were in the direction of the radii of the wheel, and whose planes were perpendicular to the central plane of the wheel, and passed through the axis about which the wheel revolved. These discs successively entered a tube in the form of a portion of

a circular anchor-ring, concentric with the wheel, and made to fit the discs. The water flowing through this tube acted on the discs with considerable force. It was a noteworthy invention, sound in principle, and capable of very varied and important applications. But no engineers appeared willing to recognize its value, so with characteristic soundness of judgment, unfailing patience, and indomitable perseverance, he set to work to apply water-power in some more popular way.

In the autumn of 1840, William Patterson, who was employed at a fixed steam engine on the railway of Cramlington colliery, being brought into contact with a jet of steam issuing from a leak in the high-pressure boiler, observed a spark pass from his hand to the lever of the safety-valve, which he was adjusting; and he experienced at the same time an electric shock. His report brought the matter under the notice of the scientific men of the day, but Lord Armstrong was the first to give the correct explanation of the phenomenon in a series of papers in the *Philosophical Magazine* in 1842 and 1843. In 1844, he exhibited to the Literary and Philosophical Society of Newcastle-upon-Tyne his hydro-electric machine, which consisted of an insulated boiler from which steam at high pressure was allowed to escape through special nozzles. The original machine was afterwards given by him to the Durham College of Science. This was the most powerful means then known of producing electricity, and it is still used when electricity of high tension is required under certain circumstances. It was so highly appreciated that it secured his election as a fellow of the Royal Society. His certificate, dated March 10th, 1846, described him as "a gentleman well-known as an earnest investigator of physical science, especially with reference to the electricity of steam, and the hydro-electric machine." It was signed by the leading physicists of that day, among whom we may notice Michael Faraday, W. R. Grove, and C. Wheatstone.

In former times, the inhabitants of Newcastle used the water of the Tyne for household purposes. This supply was subsequently supplemented from the springs at Coxlodge. But with the growth of the population the Tyne became more contaminated, and the water obtainable from Coxlodge more inadequate. In the beginning of 1845, the prospectus of the Whittle Dene Water Company was issued. The provisional

committee comprised some score of the leading citizens, and it was presided over by the Mayor, Mr. Alderman Potter; but the master mind, which directed the movement, was that of Lord Armstrong. Their plan was to divert some of the water flowing into Whittle burn, a tributary of the Tyne, and to store it in a large accumulation-reservoir about 360 feet above Tyne high-water mark, from which they proposed to bring the water through metal pipes, 24 inches in diameter, to Newcastle. These were then the largest mains in the world, and excited an amount of opposition which reflects little credit upon the foresight of the citizens of that day. At the first meeting of the shareholders on July 26th, 1845, Lord Armstrong, the moving spirit of the enterprise, was appointed secretary. He managed so well that the undertaking was a commercial success from the beginning, and from that day this growing city has enjoyed the great boon of an abundant supply of pure water. He also invented about this time, in conjunction with the late Mr. Thomas Hawksley, a valve to close the pipes automatically in the event of a leakage. This valve has been adopted by every water-company in the world, and it remains in use at the present time. At the second meeting of the shareholders, on February 25th, 1847, he resigned his secretaryship, as more important business required his whole attention.

In fact, Lord Armstrong had by this time perfected his hydraulic crane. He had long ago arrived at the conviction that water would be more useful if employed for the transmission of power than as a prime mover. On December 3rd, 1845, he exhibited, in the theatre of the Literary and Philosophical Society of Newcastle-upon-Tyne, an admirable model of a portion of the Quay, with a crane worked from the water-mains of the town. In February, 1846, he obtained permission from the Town Council of Newcastle-upon-Tyne to erect one of his cranes on the Quay at his own expense. Lord Armstrong always showed remarkable perception in his selection of those whom he employed to work for him. The man whom he chose to manage his crane became so skilful in its manipulation, that he gained the nickname of "Hydraulic Jack." So successfully did he handle it that, towards the end of the year, the crane had attracted much favourable notice. Not only was Lord Armstrong authorized to erect more cranes on the Quay, but

their fame brought many people from a distance to examine their performances. Amongst others, Mr. Jesse Hartley, the able but eccentric engineer of the Liverpool docks, was so impressed with their value, that he ordered some for his own quays. To supply this increasing demand Lord Armstrong, on January 1st, 1847, founded the Elswick engineering works, his first partners being Messrs. Armorer Donkin, Addison Potter, George Cruddas and Richard Lambert. The firm proposed to undertake all kinds of engineering work—an hydraulic engine to drive the printing presses of the *Newcastle Chronicle*, mining machinery for the lead-works at Allenheads, and winding-engines for the South Hetton Coal Company were among their earliest productions. But in spite of the genius of their able director the Elswick engineering works did not at first make very quick progress. Orders did not come in very rapidly, and there was some difficulty at starting in estimating the cost of production.

All the hydraulic machinery erected by Lord Armstrong up to 1849 was worked by water from the town mains, but in that year he received commissions for his cranes at places on the Humber and Tees, where the pressure in the water-pipes was insufficient. To avoid building a reservoir, he used an air-vessel, but the device was not entirely satisfactory. In the following year, 1850, he was engaged in the construction of some cranes for the goods-sheds of the Ferry station of the Manchester, Sheffield and Lincolnshire Railway, near New Holland-on-the-Humber. The surface of the land in this district is absolutely flat, and the ground, consisting of deep silt, afforded no foundation for the erection of a reservoir of the size necessary and of a sufficiently high elevation. He was here led to the idea of a new substitute for a large elevated reservoir. This consisted of a cast-iron vertical cylinder of considerable dimensions, fitted with a loaded plunger to give pressure to the water injected by an engine. This contrivance he called an "accumulator." It not only made it easy for him to work with water at any required pressure, but the pressure produced was more constant than that of the water in ordinary water-mains. In no previous case had he used a pressure exceeding 90 pounds on the square inch, but he now decided to work at 600 pounds. The storage-capacity of the accumulator is less than that of a reservoir, but the higher pressures employed enable the distributing pipes to be made of

smaller dimensions than would otherwise be necessary. It also rendered hydraulic machinery available in almost every situation. Being very convenient where power is required at intervals and for short periods, it has come into extensive use for working cranes and hoists, loading and discharging goods, opening and closing lock-gates, docking and launching ships, raising lifts, turning capstans, pumping water, crushing ores, and doing many kinds of useful work. It has procured important economies, and, especially where large amounts of traffic have to to be dealt with, it has saved both time and money. In the Royal navy, its applications are almost infinite in number. In spite of the rivalry of electric motors, it may still be said that a modern warship without hydraulic machinery would be an impossibility. There is hardly a manufacture of importance which has not been greatly aided by the beneficial substitution of mechanical power for laborious, and often injurious, human toil.

On November 5th, 1854, the British army won the battle of Inkerman. The victory was largely due to the gunners, who, by laboriously dragging two 16 pounders up an eminence, were able to give assistance which decided the fortune of the day. It occurred to Lord Armstrong, that, if cannon could be constructed on similar principles to rifles, they would be at once less heavy and more strong, and both more accurate and of greater range. Up to that time, guns were cast solid in a mould, and then bored along the axis. It is well-known that the strength of a homogeneous cylinder is not proportional to its thickness:—"In order to obtain the greatest resistance to bursting, the external layer must be in a state of initial tension, which should diminish in each succeeding inward layer, until a neutral point is reached; beyond which a state of compression must prevail, gradually increasing to a maximum at the interior surface."

Lord Armstrong applied himself to this problem with characteristic perseverance, energy, and thoroughness. By a series of experiments, he first proved that steel and wrought-iron were the best materials available. Then he built up his gun by shrinking red-hot jackets of twisted wrought-iron rods, welded together, on a steel core. He improved the mounting, and slides and traversing platforms were provided for the carriage to run

on. He also devised a mechanical "compressor-brake" to check recoil. This consisted of a number of short iron plates on the carriage, which interlaced with long plates or bars on the slide in such a manner that both could be clamped together by the action of the compressor-jaws. In process of time, when the size of the guns was increased, he substituted the hydraulic buffer, but as this gave trouble with the valves, it was ultimately superseded by the well-known Vavasseur system, introduced about twenty years ago.

Lord Armstrong also invented breech-loading, and devised both the screw and the wedge methods of closing the breech. He rifled the bore, and investigated the best dimensions for the charging-chamber. For round cannon-balls he substituted an elongated lead-covered projectile with an ogival head—a shape which has not yet been improved upon. In 1855, his first 3 pounder was completed, but the artillerists of the day derided it as a pop-gun. So he constructed a 6 pounder and after a long series of trials at Jesmond dene, and subsequently at Allenheads, he submitted it to the Government. This was tested in every possible way, and was found to be so satisfactory that it was adopted for the British army.

Lord Armstrong then generously and patriotically gave all his gunnery inventions to the nation, and placed his services at their command. In 1859, he accepted the post of Engineer of Rifled Ordnance, being made C.B. and receiving the honour of knighthood. A new ordnance department was erected at Elswick by a separate company, in which Lord Armstrong had no pecuniary interest. At these works, between 1859 and 1863, he superintended the construction of three or four thousand guns. Great Britain now possessed the finest armament in the world. But the Armstrong guns were very strongly opposed. They were unsuitable for exposed situations, and required careful treatment. The breech mechanism was complicated and expensive, both in first cost and in maintenance. It was not quite safe in the hands of unskilful gunners. Rivals loudly emphasized these drawbacks, and in 1863 the authorities reverted to muzzle-loaders. Apparently Lord Armstrong did not receive the consideration due to his great talents and important services. British orders were almost entirely withdrawn, but on the other hand the Elswick ordnance works were now at

liberty to accept commissions from foreign governments. These soon increased, especially as Lord Armstrong continued to improve his guns. As far back as 1855, Captain Blakeney had proposed to substitute for hoops or jackets wire wound at high tension round the core. The same idea had occurred independently to Mr. Brunel, who gave Lord Armstrong a commission for a gun constructed on this principle. This could not be executed, for it was found that Mr. Longridge had taken out a patent for it. Some time after his patent had expired, this plan of building up guns was adopted at Elswick. At present, a steel ribbon of rectangular section (0·25 inch by 0·06 inch), possessing tensile strength up to 110 tons per square inch, is wound on a steel core at a tension of about 40 tons per square inch. These guns are very strong in proportion to their weight. The defects in the breech-action were also removed and the mounting was greatly improved. Still the War Office clung tenaciously to the out-of-date, unwieldy muzzle-loaders. The British artillery fell perilously behind that of the rest of Europe, and a naval war at that time might have entailed disastrous consequences. But in 1880, our authorities were once more persuaded to adopt breech-loaders, to the great advantage of our armament.

The economical use of fuel is always an important study for a thoughtful engineer, and Lord Armstrong's attention was specially directed to the wasteful use of coal by an invitation from the Northumberland Steam Collieries Association in 1855, that he should join a small committee appointed to adjudicate a prize of £500 for the best method of preventing smoke, when Hartley coals were burnt in marine boilers. He entered into this investigation with his characteristic zeal and earnestness, and after many experiments brought out a final report in 1858. But he was so deeply impressed with the danger which threatened this country through the premature exhaustion of our coal-fields, that, when the British Association for the Advancement of Science met at Newcastle-upon-Tyne in 1863, he devoted a considerable portion of his presidential address to the probable duration of our coal-supply. He calculated that at the rate of consumption at that time Great Britain would in about 200 years cease to be a coal-exporting country. This attracted so much attention, that a Royal Commission was ordered to report upon

the subject, and his evidence was among the most valuable collected on that occasion. In 1878, when he was president of the Institution of Mechanical Engineers, he returned to the discussion of our wasteful employment of our national fuel. He estimated, that, in an ordinary engine, only about $\frac{1}{30}$th of the energy of the coal was applied to useful work, and he strenuously urged a more careful husbanding of our resources by greater economy in burning. He strongly advocated that we should take advantage of other sources of power. In 1880, he pointed out the importance of the utilization of such natural forces as waterfalls and solar heat. He calculated that the heat received from the sun in a single day upon one acre of land within the tropics would, if collected and properly applied, perform as much work as 4,000 horses could produce in 9 hours, and he suggested the possibility of contriving this by a kind of thermopile.

In 1855, Lord Armstrong was elected chairman of the Newcastle-upon-Tyne Water Company, and he continued to preside over its affairs until 1867.

Meanwhile, the Elswick works were increasing their business and growing in importance. The development was no doubt, in a great measure, the fruit of Lord Armstrong's judicious selection of able colleagues. But the enterprise owed its birth to his genius, it was fostered at first by his unceasing care, for many years it had the benefit of his constant superintendence, and up to within a short time of his last illness it was greatly indebted to his suggestions. In 1863, the ordnance works were incorporated, and about the same time blast-furnaces were established. In 1868, the firm began to build and equip warships. At first these were launched from the Walker yard of Messrs. Mitchell and Swan; but, in 1882, the two undertakings were united and formed into a public company under the style of Sir W. G. Armstrong, Mitchell and Company. Soon afterwards a shipbuilding yard was established at Elswick, which has turned out a splendid fleet of warships under the able direction of Sir William White, and later, of Mr. Philip Watts.

From an early date, Lord Armstrong had taken great interest in problems connected in the mounting and working of guns on ships. From the first, he was a steadfast believer in guns as against armour. He had himself worked at the improvement

of armour-plating. He had obtained steel of very high tensile strength and great toughness, by tempering it in an oil-bath. But after all his experiments he came to the conclusion, that the first requisite for warships was great offensive power. He held, that to render a ship safe from being sunk by modern artillery, we should have to eliminate its ability to sink anything else. At first he advocated vessels with little or no side armour, but otherwise constructed to minimize the effect of projectiles upon them. The main objects at which he aimed were high speed, great nimbleness of movement, and considerable power of offence. He accordingly devoted special attention to the design and construction of vessels of the cruiser type, which was to a large extent originated by himself. His firm built several vessels of this class, leading up to the "Esmeralda," launched for the Chilian government in 1882. Since several light cruisers could be built for the cost of a single ironclad, he argued that the former would be a better investment for the nation. A large number of ships would be necessary to guard British commerce scattered all over the world; and he believed that three or four of these lighter vessels acting together might prove more than a match for the most heavily armoured ironclad. Latterly, after the introduction of high explosives, he recommended that even cruisers should be to a certain extent protected by plates about the more vital parts.

During recent years, under the management of Sir Andrew Noble, the success of the Elswick works has been phenomenal. They have continued to increase their business, and it is said to be still steadily growing. Last year the company owned 230 acres of land, and in a single week £36,802 was paid in wages to 25,028 workmen.

In later life, the work that gave Lord Armstrong most pleasure was electrical research. In 1897, he published a beautifully illustrated work on *Electric Motion in Air and Water*. In 1899, with the assistance of Dr. Henry Stroud, professor of physics in the Durham College of Science, Newcastle-upon-Tyne, he brought out a still more sumptuously illustrated supplement This was his most important publication. He had been joint editor of *The Industrial Resources of the Tyne, the Wear, and the Tees*, which appeared in 1863. In 1872, he visited Egypt to advise the Khedive as to the best method of obviating the

interruption to the Nile traffic caused by the cataracts. His four interesting lectures to the Literary and Philosophical Society of Newcastle-upon-Tyne, describing his journey, were published in an unpretentious volume in 1874. He was also the author of a large number of papers, chiefly on scientific subjects, but some on social and educational questions. References to the more important of these may be found in the supplement to the *Dictionary of National Biography*.

In June 1886, influenced by his strong sense of duty to his country and the urgent solicitations of the party, Lord Armstrong reluctantly came forward as a unionist candidate with Viscount Ridley for the representation of the parliamentary borough of Newcastle-upon-Tyne. But, partly owing to the labour-troubles of that time, the Gladstonian candidates gained the election. In the following September he received the freedom of the city, and in 1887 he was raised to the peerage.

Lord Armstrong was Vice-President of the North of England Institute of Mining and Mechanical Engineers in 1866-67, 1867-68, 1868-69 and 1869-70, and President in 1872-73, 1873-74 and 1874-75. He was an honorary member of the North-East Coast Institution of Engineers and Shipbuilders. He was President of the Institution of Mechanical Engineers in 1861, 1862 and 1869. He was President of the Institution of Civil Engineers in 1882, which in 1850 had awarded him their Telford Medal. The Society of Arts gave him their Albert Medal in 1878, and the Iron and Steel Institute their Bessemer Medal in 1891. The Universities of Cambridge, Oxford, Durham and Dublin gave him the highest honours which it was in their power to bestow. He was decorated with orders by the Kings of Denmark, Spain and Siam, and also by the Emperors of Austria, China and Japan.

Lord Armstrong was a very notable benefactor to Newcastle-upon-Tyne, and every institution of importance in the neighbourhood worthy of support, received his generous help. The Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne, for example, is indebted to him for donations amounting to more than £14,000. He employed his genius for landscape-gardening in beautifying Jesmond dene, devoting much time and thought to it, as well as spending large sums of money upon it, and, when perfected, he presented it, with about 93 acres of land in all, a free gift to the city of his birth.

His benefactions at Rothbury were upon the same princely scale. Here, by Coquet-side, amid the haunts of his youth, he returned to spend the evening of his life, and among the beetling crags of a rugged dene he built his stately home. He laid out roads upon its rocky slopes, he trained streams, and dug out lakes. He sowed flowers, planted rare shrubs, and covered the ground with millions of noble trees, till the bleak hill-side was transformed into a magnificent park, and the barren wilderness was clothed with beauty. In 1893, he began the restoration of Bamburgh castle, but he did not live to see the completion of his great design. In spite of the unceasing care and affectionate solicitude of those who were more tender and more faithful than many children, his health failed in the autumn of 1900, and on December 27th, he peacefully passed to rest. On the last day of the century, all that was mortal of Lord Armstrong was laid in Rothbury churchyard beside the remains of his wife, in the presence of one of the most representative gatherings ever witnessed in Northumberland.

No man has been more closely identified with the utilization of natural forces to the service of man during the nineteenth century than Lord Armstrong, whose long life extended through nine of its decades. He has left us a bright example of the glory of work and of the power of perseverance. It is impossible to imagine a greater capacity for taking pains, a braver heart never discouraged by failure. With inexhaustible resourcefulness he would often learn even from disappointments the secret of success. His keen perception seized with a firm grip the essentials of a problem, and he arrived by the intuition of genius at results which mathematicians could only verify by laborious calculations. Endowed with broad sympathies and many-sided interests, he possessed in a remarkable degree the power of intense concentration on each in turn. His tact and common sense wasted no time upon wild or extravagant speculations. With unrivalled clear-sightedness he saw what was wanted, and he pursued his objects with a patient tenacity of purpose which no difficulties could daunt, no obstacles turn aside. His favourite motto was "Perseverance generally prevails." His remarkable success was largely due to his unerring judgment in choosing his colleagues and his assistants, who were encouraged to their best efforts by his wise liberality as well as

by his amiable and unselfish disposition. His kindliness of heart prompted his princely hospitality. His unaffected modesty, his gentleness and courtesy adorned an engaging personality, which attracted the sincere admiration of all who came within his influence. His fame spread through many nations. Obituary notices in every language known to civilization proved that the whole world felt poorer by his death. But simple in his habits, unassuming and free from ostentation, he lived among his own people to the end; and his memory will ever be especially beloved and honoured in the North of England.

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Mr. A. L. STEAVENSON (Durham) said that as one of the oldest members present (having joined the Institute in 1856), it perhaps devolved appropriately upon him to propose a vote of thanks to Principal Gurney for his very beautiful memoir of Lord Armstrong. In 1861, he (Mr. Steavenson) first became acquainted with Lord Armstrong's work, in connection with the hydraulic hoists which were erected at the Clarence works in Cleveland, and ever since their erection they had worked with a steady uniform speed, nor had any case of failure or breakdown ever been known in connection with them; he doubted whether any other apparatus could be produced which would give anything like the same economy.

Mr. J. H. MERIVALE seconded the vote of thanks, which was heartily adopted.

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The following paper on "The Sussmann Electric Miners' Lamp," by Mr. W. O. Wood was taken as read:—

# THE SUSSMANN ELECTRIC MINERS' LAMP.

BY W. O. WOOD.

Many attempts have been made by inventors to produce a reliable portable electric lamp for use in mines, which would be a perfect safety-lamp, and at the same time give a better light than that yielded by the ordinary oil safety-lamp, but without success, until the introduction of the Sussmann lamp.

An electric lamp is necessarily composed of two distinct parts:—(1) The battery supplying the necessary current, and (2) the lamp itself.

With the latter there has not been much difficulty: an incandescent lamp or bulb enclosed in a suitable lantern or cage being all that is necessary, provided of course that the carbon-filament has an average life.

Primary batteries were at first tried, many of them of original and ingenious design, but all that have come under the writer's observation have failed for various reasons, chiefly, because under the rough usage experienced in mines it was impossible to keep them tight, and the corrosive action of the liquids employed quickly destroyed the fittings and connections of the lamps, and the batteries themselves. The daily renewal of the elements was also a source of trouble.

The battery of the Sussmann electric lamp has solved the difficulty. It is practically a dry battery, there is neither leakage nor fumes, and it has successfully stood daily working-tests over a period of three years.

A small number of Sussmann lamps were introduced at Murton colliery in September, 1897. The result being so satisfactory as to warrant the trial of the lamp on a larger and more practical scale, 500 lamps were put into regular work in October, 1897; 100 were added in April, 1898; and 400 in September and October, 1899; making 1,000 lamps now in daily and successful operation.

At first, the Sussmann lamp was objected to by the workmen

on account of its weight (4 pounds), which is heavier than the ordinary safety-lamp, and their reluctance to use anything new; next, it was thought risky to depend upon the lamp, as it did not indicate the presence of gas. These objections were, however, by degrees removed, and the difficulties afterwards encountered were more of a practical character, particularly the extinction of the incandescent lamp or bulb, and failures of connexions and of batteries, the last being the most troublesome.

The number of failures of the ordinary oil safety-lamp, or extinctions from all causes, failure of oil or wick, being knocked over, falling down, etc., is much larger than might be expected; and it was found, on a careful record being kept, to be 2·11 per cent. of the number of lamps in use.

Even at the first, the failures of the electric lamp were not very excessive, being from all causes only 3 per cent.

At the present time, so thoroughly have all the defects and weak points been remedied, and the lamp improved, that the failures are only 0·01 per cent.: in fact it is a most unusual thing for a lamp to go out, except when crushed or broken by actual violence.

The writer feels fully justified in saying that the Sussmann lamp possesses the following excellent qualities:—(1) It is absolutely safe in an explosive atmosphere; (2) it is more reliable than an oil safety-lamp; (3) it gives double the light of an oil safety-lamp; (4) it is as portable and as easily carried as an oil safety-lamp; (5) it keeps perfectly cool in the warmest working-places; (6) it does not go out if upset or turned upside down; (7) it is more easily cleaned; (8) it dispenses with the staff of examiners required for the oil-lamp; and (9) in cases of accident, and workmen being isolated by falls or other causes, a few lamps will provide light for many hours in succession, say 9 hours per lamp, 5 lamps for 45 hours, 10 lamps for 90 hours, and so on.

Before adopting the lamp, the writer made many experiments to satisfy himself that ignition would not take place if the bulb were broken in an explosive mixture. This was done in mixtures of coal-gas and mine-gas, with incandescent lamps varying from 1 to 16 candle power, and currents varying from 4 to 110 volts. The result was invariably the same; and out of many experiments there was no ignition, while faulty oil safety-lamps, under the same circumstances, at once exploded the inflammable mixture.

*The Sussmann Lamp.*—Each lamp consists of two parts:—(1) The cage or lamp-top, containing the incandescent bulb or lamp (completely protected, and fitted with a switch for lighting or extinguishing the lamp at will) which is securely locked to (2) the battery-case with a leaden plug. The lamp is made in two patterns: Fig. 1, with an ordinary or fixed bulb, and Fig. 2, with a top (patented by the writer) containing a removable bulb, so that in the event of a bulb failing in the mine, the deputy or other official can replace it by a new one, in a couple of minutes.

Fig. 1.

Fig. 2.

*The Sussmann Battery.*—The Sussmann secondary battery is of the Faure or pasted type, and consists of 2 rectangular ebonite-cells, each cell containing 3 elements—1 positive and 2 negative. These elements are made of cast-lead plates or grids, with a stout framework tapering inwards, and are pasted or filled with oxide of lead, incorporated with a special binding material, and made into a paste with dilute sulphuric acid or sulphate of ammonia—the mass being pressed into the leaden grids and allowed to set and dry for 4 days.

When dry, the plates are placed in a bath containing dilute sulphuric acid, and are formed or converted, the positive into peroxide of lead, and the negative into spongy metallic lead, by means of an electric current. After formation, the plates are

placed in the ebonite-cells, connected by leaden strips and filled with the electrolyte. The electrolyte used in the Sussmann battery is semi-solid, the liquid-space being filled with a highly porous and absorbent compound, made conductive by saturation with dilute sulphuric acid.

The complete battery weighs 3¼ pounds, and has an electromotive force of 2 volts per cell, with a capacity of 5½ ampère-hours, which maintains the incandescent bulb for 8 to 10 hours with one charge.

All batteries, required for renewals, are made at Murton colliery, in the lamp-shop, which is completely equipped for that purpose.

*Method of Charging Sussmann Batteries.*—The batteries, having been removed from the iron cases, are placed on a suitable bench and connected in series, namely, the positive pole of one battery to the negative pole of the next battery, and so on, until the circuit is completed; the outer positive pole is then connected through an adjustable resistance-board and an ammeter, to the negative main wire from the dynamo, and the outer negative pole is connected to the positive wire from the dynamo.*

The number of batteries so connected in each circuit depends upon the voltage of the dynamo used for supplying the charging-current. There are 2 cells in each battery, so that in arranging the circuits, 5 volts should be allowed for each battery, and the maximum number of batteries in series connected to a 110 volts circuit should be 20, thus leaving a margin of 10 volts.

When the batteries are connected as above described, the current is switched on, and the resistance adjusted until the ammeter registers 0·65 ampère; they can even be charged up to 0·8 ampère, but this point should never be exceeded. Each battery has a capacity of 5½ ampère-hours, so that at the charging rate of 0·65 ampère it would be necessary to leave them connected for 13 hours, or for 12 hours at 0·7 ampère: the lower rate being preferable.

When the batteries have received this charge, they are disconnected and replaced in the iron cases, the connexion-plugs

* The charging-current must be direct, and not alternating.

from the lamps placed in the holes of the batteries, the lid closed and locked, and the lamps sent out for use.

*Dynamo.*—The dynamo for supplying the current for charging the lamps is driven by a separate engine. It is capable of delivering 75 ampères at 110 volts, at which pressure the current enters the resistance-board, referred to when describing the method of charging the batteries. The dynamo also supplies current to the 16 candle-power lamps in use in the lamp-rooms.

*Results of Working.*—The Sussmann electric lamp costs 18s. The cost of working the lamps over a period of several months, including all charges except interest on capital and the cost of running the dynamo, has been as follows:—

| | Pence. |
|---|---|
| All labour, at basis rates, including superintendence, cleaning, making ready, maintenance, etc. ... ... ... | 2·19 |
| Material for renewing batteries, repairing and maintaining the lamps in every part, and lamp-glasses ... ... ... | 1 00 |
| Incandescent lamps or bulbs ... ... ... ... | 0·60 |
| Total ... | 3·79 |
| With wages at 52 per cent. above basis rates the cost is increased by | 1·03 |
| Total .. | 4·82 |

The life of the battery, up to the present time, averages 10 months, but certain improvements have recently been made whereby it is expected to reach 12 months.

The lamps have now been in use for 3 years, and there has never been the slightest accident that can be attributed to their use. At first, it was supposed, as the lamp did not indicate the presence of gas, that men might work unconsciously in an explosive or irrespirable atmosphere; but such an event has never happened. The precautions adopted for safety are the same as before the introduction of the electric lamp. The deputies (who all carry oil safety-lamps) visit and examine the working-places before the commencement of and during the shift, and if gas be detected the men are withdrawn at once, precisely as if they were using oil safety-lamps, which, in the presence of an explosive mixture, are a source of danger while the electric lamp is

absolutely safe. The putters use oil safety-lamps, which can be used by the hewers to examine their working-places, if they suspect the presence of gas.

A careless man has been found working in a place which has suddenly become "foul," with the gauze of an oil safety-lamp red-hot and in a very dangerous condition to the individuals working in the place, and to all the men employed in the mine; but with an electric lamp this danger cannot happen. Then again, an accident to an oil safety-lamp in a "foul" place, a blow from a pick, or a fall of stone or coal, might cause a disaster, but this risk is impossible with the electric lamp, as the breakage of the bulb is followed by the instantaneous extinction of the light.

The object of introducing the electric safety lamp at Murton collieries was entirely in the interest of increased safety, which is secured by (1) the increased light, enabling the workman to make a better examination of his surroundings; (2) the use of a source of light, which minimizes and indeed absolutely removes the risk of igniting explosive gas, an element of danger which is never absent, either from accident or mistake, in the use of an oil safety-lamp. The managers of fiery mines will fully realize that they are entirely relieved of an enormous weight of responsibility and anxiety by the use of the Sussmann lamp.

In conclusion, the writer may add that he has made the foregoing paper of as practical a character as possible, and confined his remarks strictly to his personal experience gained in the use of the Sussmann lamp.

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Mr. Sydney F. Walker (London) suggested that the secondary batteries used with the Sussmann lamp should be charged singly, and not in series. There is always a danger when secondary cells are charged in series, that one or more of them may not be taking its proper current, and there will be nothing to show this, except the fact that the lamp will not last out its proper time. The best arrangement, in his opinion, would be, where an electric light or power service exists at the colliery, to put in a small continuous-current rotary transformer, arranged to deliver current at about 6 volts, to a pair of bars on

which would be fixed flexible cords with plugs attached. If the cords are of different colours, say + red and – green, it would be a very simple matter to make connection with the batteries, and to keep these cords clear of each other. Attached to one of the bars, also, should be a small galvanometer, for each pair of cords, so that the attendant could see at a glance whether any cell was not taking its charge. Simple boards, lead-covered, might be arranged with recesses for the cells, so that the work involved in setting any individual cell to charge would be very trifling. Where three-phase plant is installed at a colliery, the same plan might be adopted, the transformer converting the current into a 6 volts continuous current at one operation.

He was pleased to know that his estimate of the running cost, given in his paper, which was recently read before the Institution of Electrical Engineers, was practically confirmed by Mr. Wood's figures. His estimate was higher than Mr. Wood's figures, but it was on the supposition that battery-renewals had to be purchased complete. He ventured to think that if Mr. Wood and others, who are using Sussmann lamps, would adopt his suggestion for charging the cells, the cost for attendance would be materially reduced.

Mr. Austin Kirkup said that the Sussmann electric miners' lamp had been used at the Newbottle collieries for some months. The immediate object in giving these lamps a trial, was to obtain a better light at the working-face, so as to enable the miners to clean their coals more effectively than with oil safety-lamps. A better light was obtained, but the percentage of battery failures was much greater than appears to be the case at Murton colliery. An extraordinary number of batteries were cracked and rendered useless, by knocks which the lamps received in the pit, and this was attributed to the very light outer casing, containing the batteries. In order to reduce the weight of the lamp to 4 pounds, the makers have enclosed the battery in a very light and easily bruised iron casing, with the result that a by no means violent blow is required to damage the battery enclosed therein.

In regard to the safety of the workmen, when using this lamp in noxious gases, he could only give a qualified assent. Mr. Wood had used the Sussmann lamp for three years, and he stated that men have never been found working "unconsciously in an explosive

or irrespirable atmosphere." He had only used the lamps for six months, and yet during that time, he came across two cases of men, who were working unconsciously in an atmosphere which was unfit to breathe, owing to the presence of carbon dioxide. This occurred, in spite of the fact that the deputy had visited the place a short time before, and found it well ventilated. Fortunately, in both the cases above cited, the men were young and strong persons, otherwise they would have been overcome by the irrespirable gas. He wished to enforce the point that in workings which are liable to sudden inrushes of carbon dioxide (a very small percentage of which mixed with air is dangerous to life) the Sussmann lamp is not to be desired. In the pit to which he had referred, both fire-damp and carbon dioxide are found, and although in an explosive mixture of fire-damp and air, so long as it is not poisonous, the Sussmann lamp is to be preferred to an oil safety-lamp, yet, in the other case of a mixture of carbon dioxide and air, the Sussmann lamp is a positive danger, and is to be avoided accordingly.

In conclusion, he might mention an incident in the practical working of the lamp, where a leakage of current had occurred (due, no doubt, to defective insulation) in the lid, which surmounts the battery and forms the base of the lamp. When contact was formed between this lid and the switch spindle, a spark was produced outside the lamp. This is not desirable in a fiery pit. He did not know whether other instances of this sort had occurred, but he mentioned it to show that every care must be used to ensure complete insulation of the lamp. The lamps were under the constant charge of one of the Sussmann Lamp Company's electrical engineers, during the whole of trial period of these lamps.

Mr. Geo. Ed. Smith (Nottingham) wrote that the members were indebted to Mr. Wood for writing this paper, containing the result of 3 years practical experience with a new and absolutely safe lamp. He should like to ask Mr. Wood how he ascertained the condition of his secondary battery and, if fully charged, since the electrolite is practically dry and no fumes, that is no gas is given off, as the condition of the electrolite is generally used as an index to the good or bad condition of the cell; whether he considered a life of 10 months for the battery satisfactory; and

whether at the end of this period both negative and positive plates required renewal. Did 10 or 12 months life mean that the lamps are charged and discharged once every 24 hours for say 300 times, as he believed that the life of a battery was greatly dependent on the number of charges and discharges, rather than upon the number of months it was in use.

The PRESIDENT (Mr. J. G. Weeks) proposed a vote of thanks to Mr. W. O. Wood for his interesting paper.

Mr. T. E. FORSTER seconded the resolution, which was cordially approved.

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The following paper by Mr. Edward Halse on "Some Silver-bearing Veins of Mexico," was taken as read:—

# SOME SILVER-BEARING VEINS OF MEXICO.
(*Continued.*)*

By EDWARD HALSE.

## Real of Tasco, State of Guerrero.

Tasco is situated in a very mountainous region, about 80 miles south-south-east of the city of Mexico. The town itself is built on the side of a steep hill, at an elevation of about 5,450 feet above sea-level. A deep cañon separates it from the *cuadrilla* or hamlet of Tehuilotepec, lying 1 league to the east, where some of the principal mines are to be found.

Geologically, the region consists mainly of limestone and schistose rocks of Cretaceous age. At the surface, the Cretaceous rocks stretch in a general east-and-west direction for a length of about 60 miles, and are connected by a broad outcrop, running north and south, with the Cretaceous rocks surrounding Chilpancingo, 60 miles to the south. Surrounding these rocks are gneisses and crystalline schists of Azoic age, while, penetrating these, and ranging in a general north-west to south-east direction, are modern eruptive rocks.

Thanks to a manuscript report, written by José Vicente de Ansa, discovered not long since in Tasco, we can form a very fair idea of the condition of mining in the district during the most flourishing period of its history—the eighteenth century, and more especially the latter half of it.

Tehuilotepec was founded by François Laborde, known to Mexicans as Francisco de la Borda, in the beginning of the eighteenth century. Figs. 1 and 2 (Plate IX.) are a plan and general section of the Tehuilotepec area. On the former are shown the veins and boundaries of the claims or *pertenencias*, as well as the position of the old workings. Figs. 3 and 4 (Plate X.) are a plan and section of some of the workings, old and recent, on

* *Trans. Inst. M.E.*, 1900, vol. xviii., page 370.

a larger scale. These drawings have been reduced from plans and sections made by the engineers of the present Mexican owners of the mines.

Table I., chiefly compiled from the manuscript* already alluded to, and the explanations following it, will give some idea of what work had been accomplished in those days, and of the nature and value of the veins, the workings in which nearly all caved in many years ago.

Ansa was undoubtedly a careful observer, as well as a good miner and metallurgist, and the statistical information given by him may be relied upon as being accurate. He writes a good deal about the reduction of the ores,† as well as the state of the roads, the price of labour and materials ruling at that time, and makes some proposals with a view to lessening the cost of production, but his report failed to reach Spain.

*San Pedro and San Pablo* (A on plan, Figs. 1, 2, 3 and 4, Plates IX. and X.).—The exact position of this mine is difficult to ascertain: the bottom levels were 825 feet long, and would appear to have stretched from A to A on the plan. The mine was discovered by Borda at the end of the seventeenth century. On the northern part, a small vein (*hijuela*) was worked, called *El Pilar*, striking, according to Ansa, north-north-east (true?) and dipping 32½ degrees. This is not shown in the plan.

* "Informe al Excelentisimo Señor Ministro de Guerra y Hacienda de Indias, por Don José Vicente de Ansa, Minero Matriculado del Real de Tasco." It is dated August 22nd, 1793. In Table I., the magnetic bearings of the veins are taken from the recent plan, which was made in April, 1893. The declination at that time was 6 degrees 30 minutes east. Ansa gives the dips in fractions of a *vara* per *vara*, but in Table I. they are shown in degrees measured from the horizontal. The thickness of the veins, depth and length of workings are given by him in *varas* (1 *vara* is 33 inches nearly); these have been converted into corresponding British feet. The value of the ore is given in Spanish *marcos* and *onzas* per *carga*, or per *monton* of 100 *quintales* (1 *marco* is 7·3995 ounces troy, 1 *onza* is 0·925 ounce troy, 1 *carga* is 304·332 pounds avoirdupois, 1 *quintal* is 101·444 pounds avoirdupois); and these are converted into ounces troy per ton of 2,000 pounds. The consumption of mercury is given in *onzas* per *marco*, or in *libras* (1 *libra* is 1·0143 pounds avoirdupois) per 100 *quintales*. In Table I., the loss is shewn in ounces avoirdupois per ounce troy of silver extracted. To allow for moisture, 1 *carga* is taken as equal to 300 pounds avoirdupois, and 100 *quintales* as equal to 5 tons avoirdupois.

† For a comparison of the results of the patio process in Ansa's day with those of recent years, see Mr. R. E. Chism in *The Engineering and Mining Journal*, New York, 1889, vol. xlviii., pages 27 and 51; and for the various methods of reduction other than the *patio* used recently in Tehuilotepec, see an article by the writer in the same journal, 1895, vol. lx., page 197.

TABLE I.

| Name of Mine. | Approximate position on plans. | Strike of vein. | Dip of vein | Thickness of vein. | Ores and Matrix. | Approximate depth of workings. | Approximate length of workings. | Silver extracted per ton. | Approx. silver per ton in ore | Cost per ton mining.* | Cost per ton production.* | Loss of mercury per oz. of silver. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Feet. | | Feet. | Feet. | Ozs. | Ozs. | Dlrs.cts | Dlrs.cts. | Ozs. |
| San Pedro and San Pablo ... | A | (1) N22°W<br>(2) NNE | E<br>E, 32½° | 2¾ to 11 | Fine-grained galena, brown blende and iron-pyrites in *tenestel* (calcareous rock) | 467½ | 825 | — | — | — | — | — |
| Ascension ... | B | (1) N22°W<br>(2) N10°W | E<br>E | up to 19¼ | Similar | 275 | 82½ | — | — | — | — | — |
| San Antonio ... | C | (1) N22°W<br>(2) N10°W | E, 8½°<br>E | 2 to 11 (5½ average.) | Similar, but with *techichil* and *lechecilla* and iron-pyrites occasionally only | 178 | 137 | 40¾<br>+21<br>+16¼ | 54<br>28<br>21½ | — | — | 2·47 |
| Animas ... | D | N30°W | E, 37°<br>E, 18° lower | 1⅜ to 5½ | Similar to A and B mines. | 137 | 275 | — | — | — | — | — |
| Perdon ... | E | (1) N22°W<br>(2) N53°W | SW, 34½° | ⅓ to 2¾ | Fine-grained galena, brown blende *techichil*; matrix brass-coloured quartzose stone, sometimes gypseous (*ayesada*) | 330 | 440 | 81<br>+29 | 108<br>38½ | 14·00 | 10·00 | 1·99 |
| Dulce Nombre | F | N28°W | SW, 37° | — | — — — | 220 | — | 25¾ | 34 | — | — | — |
| San José de la Joya ... ... | G | N32°W | SW (variable) | — | Gossan with native silver above; galena, both fine and coarse-grained, below; matrix sometimes *texcal*, sometimes brass-coloured stone | 247½ | 220 | 16¼ | 21¼ | — | — | — |
| Lumbrera ... | H | N45°W | SW | ⅙ to 2¾ | Fine-grained galena, brown blende, matrix quartzose, sometimes steely quartz (*guija acerado*) | 467½ | 137½ | 82¾ | 110 | 19·20 | 14·00 | 1·37 |
| | | | | | Quartzose ores (*guijo-o*) ‡ | — | — | 40 | 53 | 17·53 | 11·98 | 2·06 |
| Lajuela ... | J | (1) N65°W<br>(2) N30°W | NE, 33°<br>NE, 26½° | 2¾ to 4⅓ | Fine-grained galena, argentite, ruby silver, iron-pyrites, brown blende, matrix quartz and *tepetate verdoso* (greenish rock, possibly diorite) | 357½ | — | — | — | — | — | — |
| San Ignacio ... | K | N56°W | NE | — | — — — | 550 | ‖ | — | — | — | — | — |
| Encarnacion ... | L | (1) N56°W<br>(2) N45°W | NE, 27° | ¾ to 2¾ | Iron-pyrites, brown blende, some fine grained galena, matrix quartz and much *techichil* | 632½ | 68¾ | 111½ | 148 | 23·00 | 14·00 | 1·92 |

* Mexican (silver) dollars are used throughout this paper. † Lower. ‡ Another kind called *abronzado*, matrix *guija acerado*, produced from 51¾ to 59 ounces of silver per ton, consuming 1·65 ounces of mercury. ‖ Right across claim.

TABLE I.—*Continued.*

| Name of Mine. | Approximate position on plans. | Strike of vein. | Dip of vein. | Thickness of vein. | Ores and Matrix. | Approximate depth of workings. | Approximate length of workings. | Silver extracted per ton. | Approx. silver per ton in ore. | Cost per ton mining. * | Cost per ton production. * | Loss of mercury per oz. of silver. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Feet. | | Feet. | Feet. | Ozs. | Ozs. | Dlrs. cts. | Dlrs. cts. | Ozs. |
| San Lorenzo ... | M | (1) N45°W<br>(2) N10°E | NE | — | — — — | 357½ | — | — | — | — | — | — |
| San Antonio ... | Santa Rosalia Hill, ¾ league south-east of Tasco | NW-SE | NE, 37°<br>23° lower. | 1⅜ to 2¾ | Native silver in quartzose gossan, and small amount of coarse-grained galena. | 220 | 137½ | 17¾ | 23½ | — | 8·72 | 2·19 |
| Pedregal ... | North-east of Tasco | NS (2) | W, 23° | — | Fine and coarse-grained galena, brown blende, yellow blende (*ojo de vivora*), matrix quartz and mica (?) (*guija mica*). | 610½ | 96¼ | 28<br>19 | 37<br>25 | 7·80<br>11·60 | 15·00<br>— | 1·98<br>1·92 |
| Compañia ... | Hill south-east of Tasco | | | | | | | | | | | |
| Alchulete ... | — | N¼NW (3) | E, to vertical | 16½ to 33 | Galena, brown blende, and pyrites in greenish quartz, between casings of gossan. | 481¼ | — | 19<br>29¼ | 25<br>40 | 5·00<br>11·16 | 9·00<br>11·26 | 1·94<br>1·81 |
| Espiritu Santo | — | — | — | 8¼ to 11 | Copper-pyrites (*bronce chino*) in common quartz with *tecacolote* between casings of gossan. | 275 | — | 20¾ | 27½ | 8·33 | 10·11 | 1·58 |
| La Huerta .. | — | — | — | — | — — — | 192½ | — | 31 | 41 | 15·86 | 10·90 | 2·01 |
| Compañia ... | — | — | W¼SW. 27° | 5½ | — — — | 536¼ | — | — | — | — | — | — |
| Nuestra Señora del Perdon ... | 6 leagues north-west of Tasco | — | 28½° | — | — — — | 247½ | — | — | — | — | — | — |
| San Onofre, etc. Llano ... | 1 long league from Zacualpan. | NW (?) | SW, 18° | 2¾ | *Metal abronzado* † and fine-grained galena in quartz between *jabones* ‡ | 330 | — | — | — | — | — | — |
| Nuestra Señora de la Luz ... | 3 leagues west of Zacualpan | NW | SW, 28½ | 1⅜ to 2¾ | Native silver scattered in quartz, fine-grained galena, iron-pyrites, blende (*maliciosa*) in quartz with *techichil*. | 275 | 137½ | 30¾ | 41 | 8·33 | 10·00 | 1·75 |

* Mexican (silver) dollars are used throughout this paper. † In Mexico, generally means copper-pyrites, but the term is sometimes applied to very rich grey copper-ore.
‡ In Guanajuato, according to Tilmann, *jabones* is a friable talcose rock, which swells and falls to pieces on exposure to the air. It is very finely bespattered with silver-ores.

*Ascension* (B on plan).—This mine was first worked by José de la Borda, the brother of Francisco, in 1740 or 1741. It was abandoned by Ansa in 1768. The vein is apt to break up into leaders which unite, up to a width of 19½ feet.

*San Antonio* (C on plan).—Pedro, the uncle of Ansa, started the workings in 1757. Down to a depth of 110 feet the ore was abundant, and gave good returns. Ansa himself got out some ore from the upper workings (*altos*), he then sank a shaft and extracted some lower-grade ore from the bottom workings, but, as the impoverishment increased with depth, he was forced to abandon it.

Ansa states that when fine-grained galena (*reluciente*) is abundant, and other *pintas* scarce, the ore is of good quality, but when coarse galena (*plomo ancho*) of the colour of brown blende (*estoraque*), and iron-pyrites (*bronce*) are present, as well as *techichil* and *lechecilla*, the grade is much lower, and the loss of mercury in reduction much greater. The two last are ferruginous and calcareous compounds respectively, both obnoxious to the *patio* process.

*Animas* (D on plan).—This mine was first worked by José de la Borda in 1771, the ore, however, proved too low grade and rebellious to pay.

Ansa describes all the above workings as being on the same vein, but it would appear from the plan that at Ascension and San Antonio, another vein, coursing north 10 degrees west, was worked as well; while, at Animas, a third vein running north 30 degrees west was opened on.

*Perdon* (E on plan).—Francisco de la Borda first worked this mine at the beginning of the century. In 1776, Pedro de Ansa worked it, but found the vein thin and the ore bunchy (*en ojos ó terminos poco durable*). His nephew took it in 1783, working in the *altos*. He then struck the vein in the San Ignacio tunnel and ran 327 feet along it in a southerly direction, when ventilation failed him. He afterwards ran in a cross-cut from the Lumbrera mine, drove some distance along the vein, and extracted a few tons of ore weekly. Ansa describes the matrix as brass-coloured quartzose stone, sometimes gypseous.

*Dulce Nombre* (F on plan).—This mine was first opened up by Miguel de Moncada, and was sold to Pedro de Ansa in 1764 or 1765. He raised from 60 to 90 tons weekly, but the grade afterwards fell, and he abandoned it in 1777 or 1778.

*San José de la Joya* (G on plan).—This mine was discovered in 1766 to 1768 by Pedro de Ansa, who won from it 150 tons weekly for a time, but, as the grade fell, he left it. His nephew worked it for a time, but failed to make it pay. The strike, according to Ansa, is north-north-east, to the south it unites with the Lumbrera and San Diego veins in the bottom working (*plan*), forming a thickness of 11 feet. It courses through hard limestone (*tiatales*), and has a variable inclination, near the surface being west-south-west nearly horizontal, and, at the junction with the other veins, being nearly perpendicular and contrary or north-east. It yields native silver only in the *altos*, in earthy gossan and blackish clay; at the junction with the other veins the ore is known as *pinta*, and consists of coarse galena of the colour of *estoraque*. In places the matrix is *texcal*, and elsewhere *piedra ametalada* (brass-coloured stone). It is impossible to identify these, but they are probably highly altered limestones, or may possibly be varieties of igneous rocks.

*Lumbrera* (H on plan).—This mine was discovered by Ansa in 1774; he raised 150 tons weekly from the mine for four years nearly, gaining a profit of $140,000, but, on the grade falling, abandoned it. His nephew worked it in 1781, and afterwards cut the vein in the San Ignacio adit, following it for 357 feet, but only met with one short length of good ore.

*Lajuela* (J on plan).—According to tradition, this mine was registered by Hernan Cortez, and was one of the first mines worked by the Spanish *conquistadores* in Mexico. José de la Borda worked it in 1745 or 1746, and Ansa in 1784.

*San Ignacio* (K on plan).—This mine boasts a similar tradition in regard to its origin: it lies upwards of 600 feet south-west of the church of Tehuilotepec. José de la Borda worked it in 1747, entering it from the last, and in eight years took out nearly $2,000,000 profit. Of this amount, he expended $550,000 on the church, as proved by accounts that were in the hands of Ansa.

When the vein became poor (*en borrasco*), he abandoned the workings, and commenced the San Ignacio adit. Some 6 or 7 years later, Pedro de Ansa continued the drift, cut the vein, and got out more than $200,000 profits. In depth the grade diminished, while the water increased, notably. The total depth reached was 550 feet.

*Encarnacion* (L on plan).—José de la Borda entered this mine from the last, and made some good profits, but, the ore getting poor, abandoned it. Pedro de Ansa tried it, got out some profits, and then left it. Finally his nephew sank the shaft 123 feet, and took out from 15 to 20 tons of high-grade ore weekly for some little time, but had to abandon it, on account of poverty, in 1787.

Two veins were worked here, the principal one being that of San Lorenzo; the other was a branch vein from the hanging-wall (*respaldo alto*) of the former. Ansa gives the strike (*rumbo*) as west-south-west, and the dip 27 degrees north-north-east (true?).

*San Lorenzo* (M on plan).—This mine was first worked by Pedro de Ansa in 1777 from the last mine. Afterwards his nephew developed it to some extent, but the vein proved to be of a patchy nature.

The *Contra Mina* or *Socabon nuevo de los Reyes* was projected by Ansa and begun in 1788, using blasting-powder and German tools and methods, with *barreteros* working in 8 hours shifts. He had driven it 673¾ feet in 1793; this point is marked in the plan. The writer examined the adit in 1894. The mouth is in a *barranca*, the elevation above sea-level being about 4,275 feet. The direction is approximately north-east, it is about 8 feet wide by 6 feet high, and driven perfectly straight. The total length now is 1,318½ feet (402 metres). The drivage on the left hand inbye is on the San Ignacio vein, and on the right is known as the San Lorenzo. The vein has a dip here of about 45 degrees to the north-east, and contains much blende and cubical iron-pyrites in a quartz gangue.

The San Ignacio adit was started in 1753 by José de la Borda, and was continued by Pedro de Ansa. In 1783, José Vicente de

Ansa began at the point approximately shown in the plan.* He cut the Lumbrera vein at 159½ feet further in, and at 192½ feet further north-east he cut the Perdon vein. He says that he continued 84 feet beyond this point towards the San Pedro and San Pablo mine, but had to give up for want of ventilation, or, as he expressed it *se me a bochorno*† *la frente.*

*San Antonio.*—This mine is situated in a mountain about ¾ league south-east of Tasco. It was worked for 40 years, and was re-denounced by Ansa in 1793. At that time he was running an adit in, and believed that he could extract 60 tons weekly.

*Pedregal.*—This mine is close to and north-east of Tasco. Ansa inherited it from his uncle Marcelo in 1781, it was then 385 feet deep. The former worked it to a depth of 610 feet, abandoning pumping operations in 1791. From 1781 to 1786 the mine produced 1,150 tons annually, the output was then increased for a time to 300 tons weekly. The mine had 3 *malacates* or mule-whims, a large windlass (*cigueña*) and, in the lower gallery, was a channel (*charqueo*) to conduct the water to the shaft-sump (*caja*).

The two veins are nearly parallel, strike north and dip west 23 degrees, they are united below. To get the water out by hand-labour Ansa says that it would take 40 *pares* (*paradas*) of miners working day and night.

*Cerro privilegiado de Compañia.*—This mine is in a hill immediately south-east of Tasco, trending east and west for about 300 feet, and about 1,017 feet high. It has three parallel veins, running a little west of north and dipping west.

* It is doubtful, however, whether this point is shown correctly in the plan, for if the Lumbrera vein was cut by Ansa in the position marked in dotted lines, this vein should have been cut in the Kings' adit, which is at a lower level. Unfortunately the level of the San Ignacio adit is not shown in the plan. Ansa says that he cut the Lumbrera vein at 58 *varas*, and the Perdon vein 70 *varas* further in, and that he drove along the latter 119 *varas*, which is the exact length of the old working shown. His starting-point was obtained by measuring outbye along the adit. The perpendicular bend in the old adit is no doubt where the adit was run along the San Ignacio vein. Either the workings shown on the Perdon vein are in reality on the Lumbrera vein, or the latter dips in a contrary direction below the adit.

† According to J. F. de Gamboa (1761) *bochorno* is "excessive heat which puts out the lights of mi es, produced by the want of ventilation, cross-cuts, etc., which is increased by the effluvia from workmen, etc." The term is now sometimes applied to fire-damp. In Spain, *bochorno,* means hot sultry weather.

There is a tradition that this mine was denounced by Hernan Cortez. It is said to have been worked for a long time, and to have been very rich. A company was formed in Ansa's time to unwater the numerous old workings; a tunnel was started 753½ feet below the top of the hill, and driven a distance of 1,723 feet. Ansa says that all the veins cut proved more or less poor (*borrascosa*). The adit was 8¼ feet wide, had two air-shafts (*lumbreras*) and a blowing-machine (*maquina de soplo*) driven by the water coming out of the adit. It was no doubt of the kind known as the *trompe* (German *Wassertrommel*).

The ore from the Espiritu Santo workings was copper-pyrites (*bronce chino*)* in a quartz-and-slate (*tecacolote*) matrix between casings (*cascos*) of earthy gossan (*ixtajal*).

The last three mines, given in the table, properly speaking, belong to the Zacualpan district. The town of this name lies about 30 miles north-west of Tasco.

The San Onofre group was abandoned through folly. Ansa formed a company to work the Nuestra Señora de la Luz mine.

The recent workings in the Nuestra Señora de los Remedios mine are shown (Fig. 4, Plate II.) and have not the irregular appearance of the old Spanish workings: to avoid confusion the former are not shown in the plan.

The old *Boca Mina* in the Espiritu Santo workings was sunk by Ansa to a depth of 257 feet on the dip.

The present Remedios shaft is vertical, and about 1,680 feet south-east of the church. One vein in the mine runs north 22 degrees west, dipping east 83 degrees, and meets near the shaft, a vein striking north 10 degrees west. At and near the point of intersection, there is an ore-shoot (*clavo*) about 160 feet long, the best portion being 33 feet in length, where the vein has a thickness of from 8 to 10 feet of argentiferous marcasite, argentite, ruby silver, a little blende and copper-pyrites in a gangue of quartz and calcite. The vein has a pay-streak (*cinta*) 15 inches thick on the eastern or hanging-wall, and another 2 feet thick on the western or foot-wall, the filling between consisting of

* This term is often applied to iron-pyrites.

limestone-country, with spots and stringers of ore, the latter roughly parallel to the walls. The centre forms the ordinary ore of the mine, carrying about 40 ounces of silver to the ton with traces of gold. The high-grade ore carries about 200 ounces of silver and 0·12 ounce of gold per ton. Outside the richer portion of the *clavo*, the vein has a width of 6 feet only, and consists almost entirely of ore of ordinary grade. At either end of the ore-shoot the vein is about 3 feet wide only, and the ore is low-grade.

The Santa Maria mine, about 840 feet higher up the cañada, is in the same north-22 degrees-west vein, the dip here being east 70 to 75 degrees. The vein in one place, below the old workings, is 3 feet wide. The ore is argentiferous marcasite and galena. It is said that five parallel veins have been worked from the surface to a considerable depth, and that they frequently intersect and separate again, *clavos* being formed at the points of junction. Near the mouth of the gallery, the vein joins with one coming from the Santa Rosa workings to the east, trending north 45 degrees west, and dipping eastward. Near the present front of the gallery, two other veins run into the main lode.

The ordinary ore of this mine, hand-picked, runs about 40 ounces of silver per ton.

By driving the main Remedios gallery 750 feet north, the Santa Maria mine would be opened up to a further depth of 270 feet vertical.

The Santo Niño is an old adit considerably to the south of the Remedios mine. It is about 650 feet in length, and rather less than 100 feet below the level of the Remedios main gallery: the latter is cleared of water by a San Pedro adit connecting with the Santo Niño near its mouth.

Three veins have been cut by this adit. The first, about 100 feet inbye, is known as Anices. It is a thin vein, consisting of small stringers of calcite of little or no value. The strike is north ½ degree east and the dip west. The second vein, about 450 feet inbye, is called the Veta Grande. It trends north 42 degrees west, dips eastward 75 degrees, and has a thickness of 8 feet of blende and marcasite in a gangue of quartz and calcite spotted

with ruby silver and argentite. The third vein, the San Augustin, has been cut 525 feet inbye, courses north 22 degrees west, dips eastward 45 degrees, and is from 8 to 10 feet thick, containing much calcite in large rhombohedral crystals (*espejuelo*). The ore consists of fine-grained argentiferous galena, marcasite, some copper-pyrites, zinc-blende, and crystals of ruby silver running in threads in solid limestone. A little further north-eastward the limestone is in thin beds. The chief workings on these two veins are on the south side of the adit, where they unite and form large *clavos*. *Buscones* work in the San Augustin mine above the adit.

The Pedregal mine, near Tasco, was worked vigorously from 1850 to 1864, and was deepened, it is said, to 984 feet. It has been under water since then.

A branch vein was being exploited in 1894. The strike is north 20 degrees west, the dip east 75 degrees, and the thickness 3·28 feet (1 metre). "On the west or foot-wall side is a streak of blende, galena, and quartz, with some ruby silver, argentite, etc., 12 inches thick, and on the east or hanging-wall is another pay-streak 6 inches to 8 inches thick. So here, as in Remedios, the pay-streak on the foot-wall is nearly twice as thick as that on the hanging-wall side. The high-grade ore yields from 185 to 237 ounces per short ton. Between the two ribs (*cintas*) there is ore of ordinary grade. The whole vein is said to average over 100 ounces of silver per ton. The formation is a calcareous schist, passing into limestone."*

A coarse red conglomerate and argillaceous sandstone (*losero* of Guanajuato also occur in the neighbourhood.†

Having thus briefly described the principal old and recent workings there remains only to consider the general characteristics of the district.

The veins of the Tehuilotepec area, may, for convenience, be classified as follows:—

(1) North-north-west to south-south-east veins (north 18 degrees west to north 32 degrees west). The most prevalent dip is easterly, about twice as many veins dipping in that as in the opposite direction.

* *The Engineering and Mining Journal*, New York, 1895, vol. lx., page 198.

† *Instituto Geológico de México*, 1896, *Boletins* Nos. 4, 5 and 6, page 161.

(2) North-west to south-east veins (north 38 degrees west to north 45 degrees west), the prevailing dip appears to be easterly, but this is not so marked as in (1).

(3) North-to-south veins (north 10 degrees west to north 10 degrees east). A few veins of this class run through about the centre of the north-north-west to north-west system of fractures. The most important is that stretching from a little north of Santa Rosa to a little south of Las Animas (D on plan): this may be regarded as a single vein, traceable for about 2,000 feet, the dip is easterly.

Among the exceptional directions may be mentioned one of the Perdon veins, north 53 degrees west (near G on plan), and the Lumbrera vein north 67 degrees west (near H on plan), both of which dip southward, while at the old Lajuela mine (J on plan) one vein north 65 degrees west dips northward; the San Ignacio vein north 56 degrees west, also has a northerly dip.

It will be observed that a vein, near M on plan, striking north 10 degrees east, forms a cross vein to the Perdon and Lumbrera veins. Instances of veins crossing each other more or less at right angles are very rare in this area: as a rule, they meet at acute angles (5 to 35 degrees). Angles of 10, 15 and 20 degrees are far more common than those of 30 or 35 degrees. It is, as might be expected, at the points of such intersections that the rich bunches or shoots of ore occur. The ore-shoots in this district are usually short, and are either mere local bunches, vertical chimneys, or show a tendency to pitch in a northerly direction.

The majority of the veins cut across the bedding-planes of the limestone-country. The writer observed in the Tehuilotepec area that the latter had a north-north-westerly dip. Nearer Tasco the beds strike east and west, and dip northward 45 to 70 degrees; hence it is by no means improbable that the pitch of some of the ore-shoots has been determined by the dip of the country.

A correct knowledge of such local laws of ore-deposition is necessary, in order to develop the mines in a rational manner.

So few points are now accessible for examination that the relative ages of the above veins cannot be positively stated.

Close to Tasco, a north-to-south direction prevails, and here the veins appear to be wider and more constant in character than those of the Tehuilotepec area.

At Tehuilotepec, the veins, as a rule, are only traceable for short distances, a few can be followed for 1,000 or 2,000 feet, *e.g.*, the north-10-degrees-west lode already mentioned (2,000 feet), and the Remedios lode, traceable for 3,000 feet. Several have actually been proved for about 1,000 feet.

The above defect may be partly due to want of development, but at the same time, the veins are undoubtedly of a pockety nature, as is so frequently the case in calcareous rock, and, as the ore-shoots occur mainly at the junction of two or more veins, the filling outside these being very low grade, there was little temptation for the old miners to follow them systematically. Nevertheless, it is highly probable that systematic development undertaken with modern appliances would pay. The driving of two deep adit-levels would prove whether the ore-shoots go down in depth, and might eventually be the means of opening up the whole area. In the northern portion the Kings' adit should be continued until the Remedios vein at least is cut. It is estimated that the Lumbrera vein would be cut at about 160 feet, the Perdon at 213 feet, the San Juan de los Hoyas (or de la Joya of Ansa) at 328 feet and the Remedios vein at from 1,000 to 1,060 feet. This adit is nearly 300 feet below the level of the Remedios main gallery. To the south, an adit might be started near the San Isidro mine at the same level, in order to open up the group of mines in that section.

While the strike of the vein appears fairly constant, the dip varies from nearly horizontal to vertical.

The thickness of the veins varies considerably from a mere thread up to as much as 20 feet. The average thickness, however, is small, probably not exceeding 3 feet, and it is only at the junction of veins or when a vein is split up into a number of stringers that abnormal width prevails.

The thickness of the veins of the Compañia group, near Tasco, is noteworthy, being from 5 up to 30 feet. The country is a schist known as *tecacolote*.*

The mineral species found in the veins are by no means abundant; leaving out the rarer specimens, they consist, below water-

* It is described as slate *(pizarra)*, or as aluminous slate *(pizarra alumbrosa)*, see *Anales del Ministerio de Fomento*, vol. v., page 522. According to Santiago Ramirez, it is derived from an Aztec word meaning crow-stone or raven-stone *(piedra del cuervo)*. The crow-stone of the North of England mines is a kind of grit.

level, and placed in order of abundance, of quartz, calcite, marcasite, iron-pyrites, blende, galena, copper-pyrites, argentite and ruby silver. In some mines, blende is very abundant, and pyrites (including marcasite) very scarce. Calcite is probably the last arrival, and the proportion of quartz to calcite no doubt increases in depth.

The structure of the veins is simple, the ore being usually in ribs or stringers, roughly parallel to the walls, and separated by gangue or by country-rock. The veins appear to have been formed partly by the filling of previously-existing fissures, cracks, joints and openings in the country, and partly by replacement of the latter. Where two ribs occur separated by more or less mineralized country there is no evidence that the latter has been broken down from the walls, and has filled a previously existing gap in the vein: the rock, although it may have been crushed and moved to a certain extent, practically forms a portion of the surrounding formation, and has been altered and partially replaced by mineral solutions which have made their way up the cracks, crevices and joint-planes, or in places have saturated the whole of the porous rock, until the latter has been entirely altered or replaced.

As in most of the silver districts of Mexico there are three vertical zones distinguishable, the oxidized or *colorados*, the sulphide or *negro* zone, and below the latter, a mineralized unproductive zone.

The surface or gossan zone is known in Tasco as *tepostel** or *ixtajal*,† when of an earthy aspect. The oxidized ores consist of oxides of iron, sometimes with azurite and native silver in small particles; but there may also be present, showing incomplete decomposition, iron-pyrites, tetrahedrite, galena and argentite. This zone has a small depth, considering the porous nature of limestone-rock, namely, an average of 130 feet. The richness varies from 26 to 80 ounces of silver per short ton. The second or rich zone reaches to a further depth of 200 feet (maximum), and contains blende (often abundant), some argentite, ruby silver, poly-

* According to Santiago Ramirez from an Aztec word meaning iron-stone (*piedra de hierro*).

† At Zacualpan (State of Mexico), sulphide of silver is often disseminated in it. *Dan el nombre de ixtajales á minerales muy oxidados, y que, por la descomposicion en que se encuentran en union de la matriz, son de muy fácil y barata explotacion. Anales del Ministerio de Fomento*, vol. v., page 411.

basite, galena, iron and copper-pyrites (latter little abundant), and bustamite (rare) with calcite and milky amorphous quartz forming the gangue. This zone averages about 100 ounces to the ton. Below it is a sub-zone of argentiferous galena, blende and a little iron-pyrites, quartz and calcite, averaging from 25 to 40 ounces per ton. The third or unproductive zone is reached at a comparatively shallow depth, or a little over 700 feet, in this district.

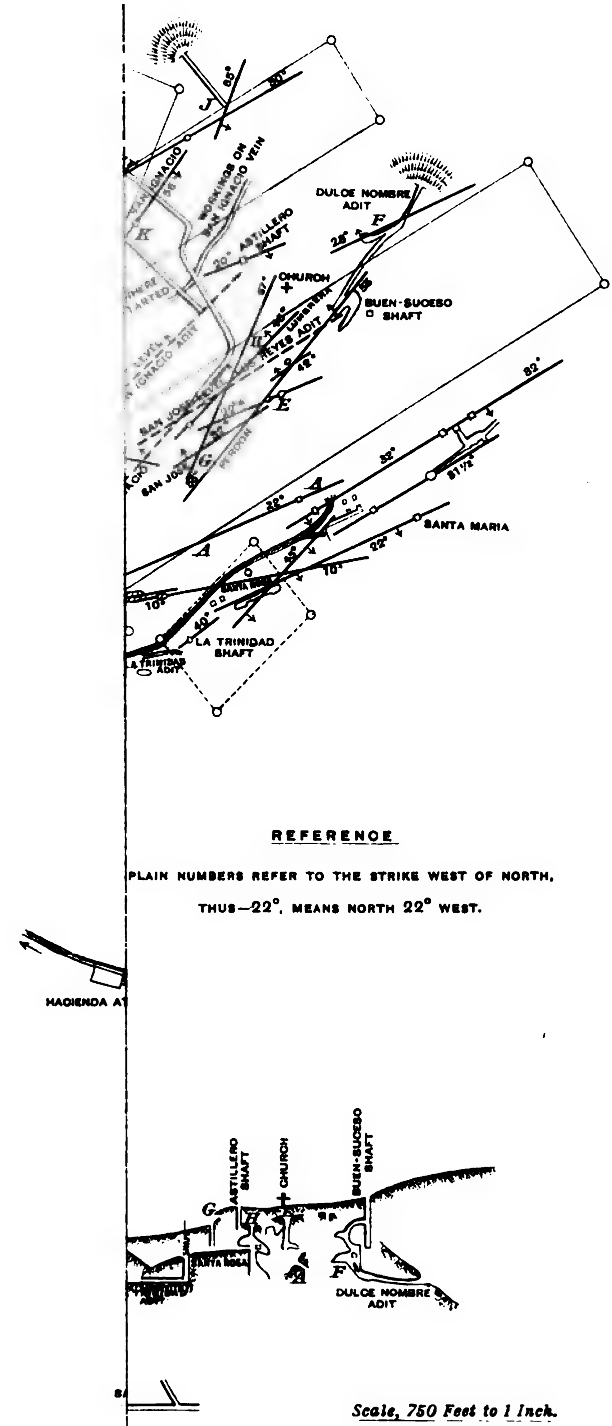
The ores are notoriously rebellious when treated by the *patio* process. This is shown by the high loss of mercury given in the last column of Table I. and appears to be due to the presence of much lime and iron in the ore. A sample of the ordinary ore from the Remedios mine, giving 40·83 ounces of silver per ton, yielded of iron (estimated as oxide) 16·20 per cent., while the zinc was only 0·08 per cent. and the copper 0·12 per cent. The average loss of the mercury in treating the Remedios ores by the *patio* process a few years ago was 1·5 ounces per ounce of silver extracted, while the loss in the Tehuilotepec ores treated in Ansa's day varied from 1·37 to 2·47, the average being 1·96. The ores near Tasco would appear to be slightly less rebellious, the average having been 1·84, and in these mentioned as occurring in the Zacualpan district the average loss was 1·81.

The loss of silver in reduction in Ansa's day was probably about one-third; the loss in recent years in the *patio* process was one-quarter.

In Guanajuato and Pachuca, the *patio* process is still largely used, the percentage of silver extracted being as high as 90, and in some instances, it is claimed, 95.

It must be admitted that the ores worked by Ansa, with a few exceptions, were by no means high-grade. The average extraction given in the Table is 36½ ounces per ton, and allowing one-third loss in reduction the average silver content in the untreated ore comes out as 48¾ ounces. But the ore was no doubt hand-picked before being treated, so that the average silver contents in the workable portions of the vein would probably not have exceeded 35 to 40 ounces of silver to the ton.

Several of the mines worked at a profit by Ansa would not pay the cost of working at the present price of silver. It would be interesting to know what the average yield of the big bonanza (that of San Ignacio) was, but Ansa does not tell us, as this was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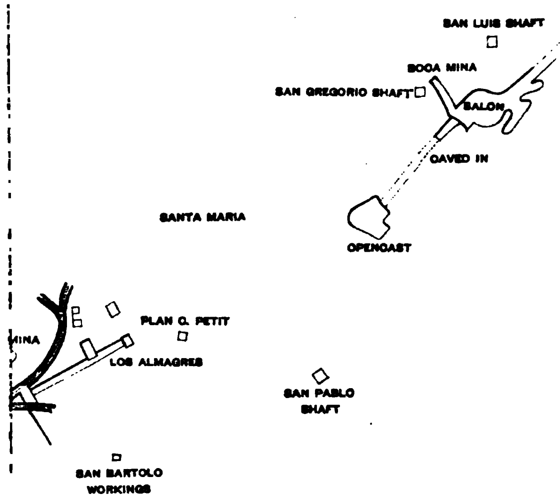
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SAN PABLO
SHAFT
SAN BARTOLO
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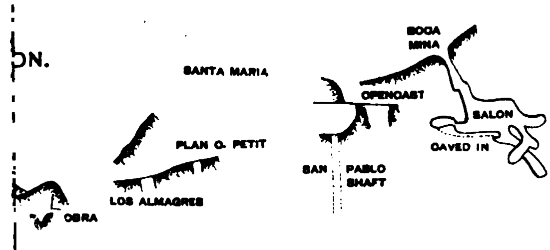
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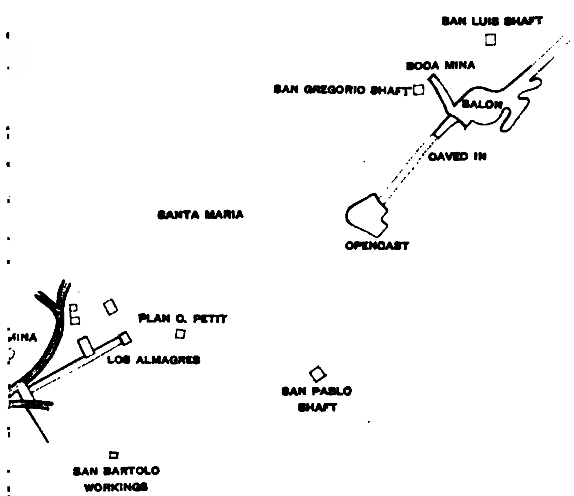
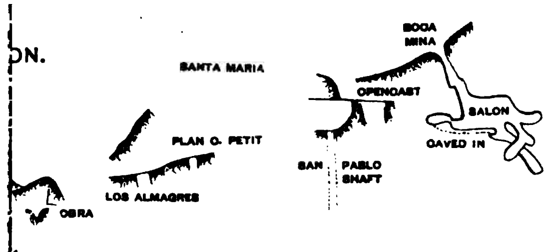
Vol. XXI, Plate X.




North

Vol. L, Plate XIV.

worked out before his time, and no accurate records seem to have been kept by his predecessors.

To those owning mines or contemplating mining in this district, the data given by Ansa must prove of considerable interest and value. It is necessary, however, to bear in mind that the price of silver in Ansa's day was rather more than double what it is now. Moreover, labour and living expenses were remarkably cheap. Indeed Ansa says that the abundance and cheap price of provisions was then one of the great impediments to mining. This sounds like a paradox, but he explains that with maize at from 6 to 12 reales the load, the miner could in a few shifts buy half a bushel (*fanega*), and by paying 1 real for meat, 1 for beans (*frijoles*), 1 for lard (*manteca*), and ½ real for red peppers (*chiles*), he and his family were supplied for a week, and then had sufficient left to cultivate their vices!

Miners worked from Monday to Wednesday on which day it was customary to pay them $1 (for the three days' work), the remaining four days of the week being taken as a well-earned holiday. The numerous saint's days so rigidly observed by the pious miner of the present day appear to be a small evil compared with the old system. Common labourers, ore-and-rubbish carriers (*faeneros*) were paid 2 reales a day only.

Owing to the crude methods of mining in those days, and the high price of materials, the average cost per ton of mining and reducing ores of ordinary grade comes out at $22.

Taking into consideration the amount of dead-work necessary to develop the mines, and the nature of the ores, it is doubtful whether the total cost per ton at the present day would be much less than this, and it might well be more. In short it is doubtful whether it would pay to win ores in this district that contain less than 30 ounces of silver per ton.

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Since the preceding paper was written, it is reported that the Tehuilotepec group of mines has been purchased by an American, so there now seems a probability of the area being worked on a proper scale.

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The PRESIDENT (Mr. J. G. Weeks) moved a vote of thanks to Mr. Halse for his valuable paper.

Mr. A. L. STEAVENSON seconded the resolution, which was cordially approved.

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Dr. G. A. F. MOLENGRAAFF'S "Remarks on Mr. Wm. Taylor Heslop's Paper on 'The Coal-fields of Natal,'" were read as follows:—

# REMARKS ON MR. WM. TAYLOR HESLOP'S PAPER ON "THE COAL-FIELDS OF NATAL."*

By Dr. G. A. F. MOLENGRAAFF (Pretoria, Transvaal).

In the introductory part of his paper, Mr. Heslop gave a geological classification for South Africa, which was stated to have been proposed by the writer. But, in reality, he had never adopted such a scheme, and somehow a mistake must have been made. Therefore he would give, in Table I., the classification† which he proposed for South Africa.

As to one of the principal matters dealt with in the two papers, namely, the geological position of the South African Coal-measures, it was indeed a problem beset with great difficulties. He entirely agreed with Mr. Heslop and Mr. C. Wilson-Moore where they argue that the coal-deposits at Vereeniging and in the vicinity of the Witwatersrand belong to the same geological horizon as those in the eastern part of the Transvaal, principally in the districts of Middelburg, Ermelo and Vryheid, and those in Natal. Both stratigraphical and palæontological evidence are in favour of this opinion. The fact, that at Vereeniging, the coal-seam lies almost immediately upon the Dwyka Conglomerate, whereas in the Vryheid district and in Natal the one is separated from the other by about 800 feet (more or less) of sandstone, without coal-seams, and moreover by the Ecca Shales, must be explained by the thinning out of the lower part of the Upper Karroo‡ and of the Ecca Beds from east to west. The

* *Trans. Inst. M.E.*, 1900, vol. xviii., page 410; and vol. xx., page 182.

† (1) *Rapport van den Staatsgeoloog over het jaar* 1898, Pretoria, 1899. (2) *Geologische Aufnahme der Süd-Afrikanischen Republik, Jahresbericht für* 1898, Pretoria, 1900. The English translation of this report is ready for the press, but its publication was interrupted on account of the war. (3) "Die Reihenfolge und Correlation der geologischen Formationen in Süd-Afrika," *Neues Jahrbuch für Mineralogie*, etc., 1900, vol. i., page 113. (4) A somewhat different and less complete scheme had been given by him in the *Annual Report of the State Geologist of the South African Republic for* 1897, and in the *Transactions of the Geological Society of South Africa*, 1898, vol. iv., page 129, Johannesburg, but this scheme also was very different from the one quoted by Mr. Heslop.

‡ To avoid all ambiguity, it might be remembered that he called "Lower Karroo" the beds of glacial origin, namely, the Dwyka Conglomerate and the Ecca Shales, and "Upper Karroo," all the remainder of the Karroo System, that is, the Hoogeveld formation or Beaufort Beds and the Stormberg Beds. He found it convenient to distinguish in the Vryheid district two subdivisions in the Hoogeveld formation, namely, the "Lower grit and sandstone" without Coal-measures, and the "Upper grit and sandstone" with Coal-measures in its lower part.

mere fact that the coal-seam at Vereeniging is so very near the underlying Dwyka Conglomerate cannot justify Mr. E. J. Dunn's* hypothesis, according to which an extensive deposit of coal ought to be found, or at least searched for, in Cape

TABLE I.

| Age. | Cape Colony. | Transvaal. |
|---|---|---|
| Jura. | Uitenhage Formation. | ... . ... |
| | ~~~~~~ | |
| Lias? | Enon Formation. | ......... |
| | ~~~~~~ | ~~~~~~ |
| | **Karroo System.** | |
| | **Upper Karroo, Fluviatile and Lacustrine.** | |
| Trias. | Stormberg Beds with Coal-measures. | Stormberg Beds? and Igneous Rocks of the Lebombo. |
| Permo-Carboniferous. | Beaufort, *Dicynodon* or Karroo Beds. | Hoogeveld Formation, with Coal-measures. |
| | **Lower Karroo, Glacial.** | |
| | Ecca Beds and Dwyka Conglomerate. | Ecca Beds and Dwyka Conglomerate. |
| | ~~~~~~ | ~~~~~~ |
| | **Cape System.** | |
| | ......... | Waterberg Sandstone. |
| | Witteberg Beds. | Plutonic Series of the Bushveld, Red Granite, Elæolite-syenite, Norite, etc. |
| Devonian. | Bokkeveld Beds. | { Pretoria Series. Dolomite Series. |
| | Table Mountain Sandstone. | Black Reef Series. |
| | ~~~~~~ | ~~~~~~ |
| | **South African Primary System.** | |
| | ......... | Witwatersrand Series. |
| | ...... ... | Barberton or Hospital Hill Series. |
| | ... ..... | Crystalline Schists and Old† Granite. |

~~~~~~ Represents unconformable succession of the formations between which it is placed.

Colony near the base of the Ecca Beds just above the Dwyka Conglomerate. In fact, the formation in which the coal-seam at Vereeniging occurs, has nothing to do with the Ecca Beds, but forms part of the Upper Karroo, the Ecca Beds at

\* Mr. E. J. Dunn, *Report on a Supposed Extensive Deposit of Coal Underlying the Central Districts of the Colony*, Parliamentary Paper, Cape Town, 1886.

† Old, in distinction from the much younger Red Granite.
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Vereeniging being not developed or hardly so, and equally the grits and sandstones devoid of coal-seams, which form the lowest stage of the Upper Karroo in the Vryheid district, have dwindled down to almost nothing. So it is evident that the occurrence of coal at Vereeniging cannot possibly give an inducement to expect coal to occur elsewhere in the Ecca Beds.

So one may safely conclude with Mr. Heslop and Mr. C. Wilson-Moore that the Coal-measures in the Transvaal and those in Natal belong to the same geological horizon; but with the Coal-measures in the Cape Colony, the Stormberg and Indwe coal-fields, it was, in his opinion, a very different matter.

Palæontological evidence is decidedly in favour of a difference in geological horizon between the coal-seams in the Transvaal and those in Cape Colony. According to palæontologists of authority, such as Messrs. Feistmantel,* Seward,† and Zeiller,‡ the flora of the Coal-measures in the Transvaal (and therefore also in Natal) indicates the Permo-carboniferous age of those beds, whereas the flora of the Stormberg Beds indicates a younger, probably Triassic age for these strata.

Introducing the generally adopted divisions of the Karroo System, this means that the Coal-measures in the Transvaal and Natal should belong to the Beaufort Beds of Dr. Feistmantel and the Coal-measures in the Cape Colony to the Molteno Beds, that is, to the lowest stage of the Stormberg Beds. Now it was his opinion, that so long as a systematical survey of the entire Karroo System, which possibly might give another perhaps quite unexpected solution, was wanting, one had to yield to the strong weight of palæontological evidence. The interpretation, which seemed to be best in harmony with the facts known until now, was the following:—

In the Transvaal, only the lower division of the Upper Karroo is developed and in it is found a horizon with coal-seams.

* Dr. O. Feistmantel, "Uebersichtliche Darstellung der geologisch-paläontologischen Verhältnisse Süd-Afrikas: 1. Die Karroo-formation und die dieselbe unterlagernden Schichten," *Abhandlungen der königlichen böhmischen Gesellschaft der Wissenschaften*, vol. iii., Prag, 1889.

† Mr. A. C. Seward, "Note on the Plant-remains from Vereeniging, Transvaal," *Quarterly Journal of the Geological Society* of London, 1898, vol. liv., page 92.

‡ Prof. R. Zeiller, "Etude sur quelques Plantes fossiles, en particulier *Vertebraria* et *Glossopteris*, des environs de Johannesburg, Transvaal," *Bulletin de la Société Géologique de France*, 1896, series 3, vol. xxiv., page 349.

He had called this formation the "Hoogeveld formation,"* and it must be taken to be of the same age as, and equivalent to, the Beaufort Beds in Cape Colony. This formation is thickest in the south-eastern districts of the Transvaal, namely, Vryheid and Utrecht, and in Natal, and thins out very much to the west. So too the lower grit and sandstone, underlying the Coal-measures in the Vryheid district and in Natal are reduced to vanishing-point at Vereeniging† and in the vicinity of the Witwatersrand. Generally it is now accepted, on the authority of Messrs. Schenck and Dunn, that the Coal-measures in the Transvaal belong to the upper division of the Upper Karroo, namely, to the Stormberg Beds which should overlap to the north over the Beaufort Beds. But this opinion seems to be erroneous, and probably the Stormberg Beds do not occur in the Transvaal, unless perhaps in the faulted strip of the Karroo along the Lebombo mountain-chain. As to the upper stages of the Stormberg Beds, namely the Red Beds and the Cave Sandstone, it is certain that they do not occur to the north of the latitude of Winburg, where they are found with a continuous gentle dip to the south, and no trace of these formations is ever found in the Transvaal. As to the lowest stage of the Stormberg Beds, namely, the Molteno Beds, it is probable that they also are not found in the Transvaal. So it seems that one has to accept the existence of two coal-bearing horizons, an upper one, in the Molteno Beds (*id est*, the lowest stage of the Stormberg Beds), and a lower one in the Hoogeveld formation which is most probably equivalent to the Beaufort Beds. The strata in which the upper one is found apparently do not occur in the Transvaal: either they were never developed there, or they were afterwards entirely removed by erosion and denudation. The lower one has not yet been found to be coal-bearing in Cape Colony. It must, however, be clearly understood that, although he considered it for the present advisable to accept the

* In his publications, which he quoted on a previous page, he had not yet broken with the generally adopted opinion that the Hoogeveld formation, with its Coal-measures in the Transvaal, should belong to the Stormberg Beds, but he discussed in these (No. 2, page 24, and No. 3, page 118) the possibility of his opinion being false, and the probability that the Hoogeveld formation should be correlated with the Beaufort Beds in Cape Colony. Later, he had obtained more convincing evidence on this point.

† As already mentioned above, the Ecca Beds also, belonging to the Lower or Glacial Karroo, have dwindled down so much here that the coal-seam is lying practically on Dwyka Conglomerate.

existence of two horizons of Coal-measures, yet he did not agree with Mr. Dunn, who wished to search for the lower horizons in Cape Colony at the base of the Ecca Beds. It is in the Beaufort Beds that one ought to search for this lower horizon of Coal-measures. But it would be unwise to form too great expectations regarding those searches. We must bear in mind that the coal-deposits in South Africa originated from the accumulation into lakes, valleys, or depressions, of vegetable débris transported by floods, and therefore they must possess a more or less local character. So the probability is that the same horizon, which is coal-bearing in the Transvaal, may be found entirely devoid of coal-seams in Cape Colony, and *vice versa.*

In conclusion, he wished to state that he had suggested the interpretation given here above only as a possible one, and that the problem remained open and could only be solved conclusively by new stratigraphical and palæontological researches in the Karroo, to be carried out along the entire track of ground from Cape Colony to the Transvaal. But so long as new facts had not been found in support of the theory of the existence of only one single coal-bearing horizon in the Transvaal, Natal, and the Cape Colony, he considered the rather uncertain stratigraphical data* which could be quoted in its favour, insufficient to permit us to disregard the value of the palæontological evidence, which leads to a different conclusion.

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The PRESIDENT moved a vote of thanks to Dr. Molengraaff for his interesting notes on the geological classification of strata in South Africa.

Mr. R. A. S. REDMAYNE seconded the resolution, which was cordially adopted.

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* The similarity in the altitudes at which the Coal-measures in South Africa are found (between 4,900 and 6,100 feet above the sea-level, that is where they are not faulted down), has also been used as an argument in favour of their belonging all to one geological horizon. This argument would be of great value if the Upper Karroo Beds, where not faulted, were lying perfectly horizontal, but such is not the case. In the Drakensberg, north of the Tugela there is a general dip to the south, which, although it is very feeble, causes great differences in level of the same bed, where we have to deal with such enormous distances. Compare Mr. David Draper "On the Coal-deposits of South Africa," *Transactions of the Geological Society of South Africa*, 1898, vol. iii., page 128.

## DISCUSSION OF MR. WM. TAYLOR HESLOP'S PAPER ON "THE COAL-FIELDS OF NATAL."*

Mr. J. M. LIDDELL (Stocksfield) wrote that he had read Mr. C. Wilson-Moore's comments on this subject, and thought that their most important feature was his concurrence, after a careful review of South African geology, in the opinion that the theory of an older and deeper formation of coal-beds in Cape Colony is unfounded; and that the field more or less proved and developed in Natal, the Orange River Colony, and the Transvaal, is the only source of native coal-supply to be considered. He gathered from Mr. Taylor Heslop's paper that, since the date of his (Mr. Liddell's) visit to Dundee, the Natal coal-field has been fairly well proved in extent and character, and that nothing is likely to be discovered that will surpass the Dundee colliery in the value of its seam or in general advantages. It is therefore evident that the Dundee colliery and its immediate neighbours are the principal native source upon which Natal and much of South Africa must depend for their industrial supply. Mr. Taylor Heslop seems to show that the Dundee colliery amply fulfils the expectations formed regarding its development, and that its output has increased at a rapid rate and may be expected to continue so increasing in the future. In this view it is important to secure every ton of coal that can be raised without actual loss, for though the reserves of available coal now existing may be extensive, a few years work may bring the question of exhaustion into serious prominence. He would suggest that the bottom seam, which is shown in Mr. Taylor Heslop's section as 1 foot of coal separated from the main seam above by 1 foot 1 inch of stone band, should be carefully considered, with a view to recovery. It would of course be unprofitable to touch it after the main seam of 4 feet has been goafed and abandoned, but, as the latter allows ample room in the bords for the stowage of waste stuff from this band, he thought that it might pay to rip the bottom after working or while working the main seam, and to recover this foot of coal. It would probably be mostly round coal, and might add considerably to the life of the colliery. Say 480 acres of 1 foot of coal, giving perhaps 500,000 tons, or 100,000 tons a year for 5 years of colliery life. He noticed that there was no mention of any

* *Trans. Inst. M.E.*, 1900, vol. xviii., page 410; and vol. xx., page 182.

attempt having been made to utilize the duff-coal left after screening. He had occasion to try a sample of coal some years ago, which had come from a seam discovered near Newcastle, Natal, and he found that after crushing and washing, it produced a very fair looking sample of coke. Possibly the duff at the Dundee colliery might also be turned to account in this way, as there was a good supply of water and, if he remembered correctly, some clay in the neighbourhood; or it might be burned under boilers by forced draught, as much refuse coal was now burned in this country.

The war was changing very greatly the conditions of life in South Africa and should, he thought, give a desirable opportunity for re-organizing labour. It was, he believed, the opinion of many men of South African experience, that after the disposal of the Boer question, there would be a native question of immense importance to be dealt with. He, therefore, questioned the wisdom of letting this industry remain dependent on coloured communities, either Kaffir or Indian. He noted that Mr. R. A. S. Redmayne agreed with him as to the unsatisfactory character of Kaffir or coolie labour for mining, and he did not think that employers at all realised the great increase of expense, and the hindrance to mining work inseparable from it. The lower earnings per man per day and the cheaper outlay per house are conspicuous, and were, therefore, much considered; perhaps also the indirect profits arising from the procuring and management of coloured labourers with their peculiar languages. But the erratic character of Kaffir periods of labour, the low tonnage per man of all coloured labour, involving extra pit-room and plant, and its liability to wholesale drunkenness and disease, were lost sight of when reckoning outlay and costs, or were passed over as inevitable evils. There was much to be said in favour of compact and pliable communities of machine-using white men, not least perhaps for the facilities that they gave for estimating capital outlay and current cost, also for time involved and quality of work produced; and he thought that the high cost of housing and feeding white labourers should be capable of great reduction after the war. Having so wide and clear a view of this coal-field and of its industrial possibilities at this early stage of its development, it might be hoped that its history would show a successful example of exhaustive and economical exploitation.

Mr. WM. TAYLOR HESLOP, replying to Mr. John M. Liddell's reference to the possibility of finding an anthracitic coal of definite value for naval purposes,* wrote that the high ash, as compared with Welsh semi-anthracite, retarded combustion and made the coal too slow-burning in character for naval requirements. With careful supervision of the firing, some of the semi-anthracites, with not less than 14 per cent. of volatile matter and not more than 8 per cent. of ash, might meet local requirements, but established prejudices were difficult to overcome.

The labour-supply for the mines was an important matter. Kaffir labour is unreliable and requires a regular system of touting or recruiting to maintain a supply. Coolie labour is much cheaper, but less efficient than Kaffir labour; it has, however, the compensating advantage of being regular in character. There are now 1,050 coolies employed in Natal collieries. The all-white staff of labour suggested by Mr. Liddell is out of the question with the present heavy customs tariffs on foodstuffs in force in Natal.

The lack of topographical maps is, as mentioned by Mr. Redmayne,† a great drawback both in mining and in warfare. The map compiled by the military authorities during the early stages of the war is the only one of any definite value, but it is not, as yet, available to the general public, and in many features it is only a sketch-map.

The writer agrees with Mr. C. Wilson-Moore‡ that the preponderance of evidence is in favour of the South African Coal-measures being of Triassic age. The only difficulty is the explanation of the survival into them of Carboniferous fossils.

There is sufficient evidence of the columnar structure of the dolerite, although it is not always apparent. In the intrusive sheets, the columns stand vertically, and in the dykes they lie horizontally, that is, they are at right angles to the bedding. This structure often forms the only index as to whether a dolerite is a dyke or a sheet. The rule laid down "that roughly speaking, the coal is found unaffected at a distance from the dyke, equal to the thickness of the dyke" can of course only be taken approximately. Recent observations of dykes from 12 feet to 25 feet in thickness at the Dundee and Navigation

* *Trans. Inst. M.E.*, 1900, vol. xviii., page 428.

† *Ibid.*, vol. xviii., page 429.

‡ *Ibid.*, vol. xx., page 182.

collieries serve to confirm this rule. It is evident from the laws of heat that the amount of heat given out by the molten dolerite would be proportional to its cubic contents, and not to its width, but the distance affected would be modified by the conductivity of the strata. The rule cannot therefore be applied to very thick dykes, and the observation of a dyke 3 feet in width shows that it cannot be applied to very thin dykes. A sandstone contiguous to and overlying 150 feet of dolerite was fused to quartzite for a thickness of 2 feet.

Since writing the paper, the expectations of the exportation of coal to Cape Colony have been realized, and four of the Natal collieries are now supplying coal to the Cape Government railways. The demand for coal has considerably increased, and the output is only limited by the ability of the railways to carry it.

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## DISCUSSION OF DR. C. LE NEVE FOSTER'S PAPER ON "METHODS OF PREVENTING FALLS OF ROOF, ADOPTED AT THE COURRIERES COLLIERIES,"* AND MR. E. REUMAUX'S PAPER ON "THE EMPLOYMENT OF IRON BARS AT THE No. 6 PIT, LENS COLLIERY."†

The President (Mr. J. G. Weeks) drew attention to the circular issued from the Home Office on March 15th, 1901, accompanied by a *Report of Four Inspectors of Mines on the Methods of Preventing Falls of Roof adopted at the Courrières Collieries*, to all owners and managers of collieries. He (Mr. Weeks) did not consider that the system of timbering therein recommended was applicable to the mines of Durham and Northumberland. It would be observed, on carefully reading the report, that the coal at Courrières was worked by the method known in this district as "scalloping," and this system would not suit the steam-coal collieries of the North of England, where they had to undercut and shoot down the coal. At Courrières, they had a very hard thill and a very soft roof, so soft that they could practically rip it with a hack instead of shooting it; and such conditions did not exist in North of England mines. The

* *Trans. Inst. M.E.*, 1901, vol. xx., pages 164 and 209; and vol. xxi. page 116.

† *Ibid.*, vol. xx., page 206.

particulars given in the report of the four inspectors, which applied equally to all French mines, covered both roof and sides as well as falls of coal; and, comparing their figures with those of collieries where they had a shooting seam, a considerable distinction must be drawn. The average percentage of deaths in the five years, 1895-1899, in the Newcastle-upon-Tyne mines-inspection district was stated to be 0·59 per 1,000 persons employed; in the whole of France in the five years, 1894 to 1898, it was 0·58; and at the Courrières collieries, the average over the last 10 years was 0·15. But at one of the collieries in Northumberland, the average over the past 20 years was 0·07 per 1,000 persons employed,* so that actually there were large collieries with a very much smaller death-rate than the best collieries in France, and the Newcastle-upon-Tyne mines-inspection district as a whole was practically equal to the whole of France. The system recommended might be suitable to the Courrières collieries, but its extension throughout France had not been enacted by the French government, so that in all probability the system was not applicable to other French collieries.

The Home Office had not recommended that the Courrières system should be adopted in Great Britain, but they trusted that the perusal of the report might "assist in the adoption of methods of timbering, which will reduce the very serious loss of life, and the great number of cases of injury, which are caused by falls in coal-mines." Mining engineers were bound to accept the report in the spirit in which it was put before them, and if they could do anything to reduce the loss of life in mines they would of course do it; but at the same time they could not close their eyes to the fact that the adoption universally of the method proposed by the Home Secretary would not be of any use. Their duty was to adopt the best means under the particular circumstances with which they had to deal, and they must remember that the conditions varied not only in different collieries, but in different parts of the same colliery from time to time.

Mr. R. A. S. Redmayne (Seaton Delaval) thought that the report of H.M. inspectors of mines could not be taken as a criterion of the manner in which the mines in the North of England should be timbered. He thought that the diminution in the loss

* *Trans. Inst. M.E.*, 1901, vol. xx., page 173.

of life at the Courrières collieries was due to increased supervision, rather than to the particular method of timbering adopted. When the system of timbering was changed, increased supervision came into vogue at the same time, as stated in the report.* The report did not state whether the "shale" was hard or soft, or whether it was simply underclay. He was inclined to the latter belief, for the report stated that "the working-places we inspected were in a part of the mine where the seams are completely overturned: the actual roof being formed by the underclay or thill, containing many slippery joints or 'backs,' and occasional 'pot holes.'"† If they had a roof in a Northumberland or Durham colliery, such as that at the Courrières collieries, they would possibly adopt the same method of timbering; but to suggest that this method should be adopted throughout the length and breadth of the county was preposterous.

Mr T. E. Forster (Newcastle-upon-Tyne) regretted that the accidents due to falls of roof could not be separated from those caused by falls of coal. H.M. inspectors of mines, in future, should separate these accidents, as they were the only people who had the requisite information. In this part of the country, a great proportion of the accidents arose when working the hard coal and kirving long distances, by juds coming down through not being properly spragged, and so on. At Courrières collieries, they had a different seam and a different class of roof, and even though they might wish to apply the method in Northumberland to-morrow it could not be done. The system would reduce the percentage of round coal, and the proportion that the quantity of coal bore to that of the timber required.

Mr. Henry Palmer (Medomsley) remarked that the report of H.M. inspectors of mines afforded no clue as to the percentage of the improved conditions at Courrières collieries due to the better system of supervision. In the North of England, they had always prided themselves on their method of supervision—the deputy system—and they looked to that in a great measure for the comparative immunity from accident which they enjoyed, compared with Lancashire or South Wales. He did not know whether other members had heard the same statement, but he had been told emphatically that in France unless an accident

* *Report of Four Inspectors of Mines*, etc., page 3. † *Ibid*, page 6.

proved fatal within seven days of the accident happening the death was not considered to be due to the accident, and if that were true it might materially alter the figures put forward. He would like to draw the attention of the members present to the leading article in the *Mining Journal*, which appeared to be an able one and well worthy of the careful attention of mining-engineers and colliery-managers.*

Mr. T. E. FORSTER said that Table I.† shewed that the result of the increased supervision during the period 1880 to 1889, with the exception of the year 1883 (which was a very bad one), was very satisfactory. He did not think there was any other district but Northumberland and Durham in this country where the timbering was done by a special set of men, nor was the timbering done anything like so well as it was done here by the "deputies."

The PRESIDENT (Mr. J. G. Weeks) referring to Table I.‡ said that during the first period of 10 years (1870 to 1879) there were two years free from accident; during the next ten years there were six years without accident, and in the last 10 years only four. Notwithstanding this, the general average of the last 10 years was 0·15, as compared with 0·24 per 1,000 persons in the middle period. He had no doubt that the increased safety to a large extent was due to better supervision, and the question might arise as to whether there was any necessity for increased supervision in Great Britain. He did not think so as regards this district, but he thought that the following paragraph in the report ought to be questioned, as it was stated that "the main point requiring attention, and the one which, in the opinion of the Courrières engineers, most largely conduces to the prevention of accidents, is that supports must be put in as soon as there is room, and that under no pretext may the timbering be delayed 'until a more convenient season,' as is so often the case in British collieries."§ This dilatoriness certainly did not obtain in the North of England, for the men did not delay in putting in a prop "until a more convenient season." If a deputy saw that a prop was wanted, it was always put in at once. If this statement applied

* *Mining Journal*, April 6th, 1901, vol. lxxi., page 389.

† *Report of Four Inspectors of Mines*, etc., page 9. ‡ *Ibid.*, page 9.

§ *Ibid.*, page 8.

to other districts, H.M. inspectors of mines in those districts should see that the practice was altered, and that the timbering was done in a more efficient way. He thought that it was very undesirable to alter their methods of timbering, which the experience of many years had proved to be the best adapted for their district.

Mr. Henry Palmer said it would appear that H.M. inspectors of mines, who had written the report, were not acquainted with what was done in other districts, seeing that a method similar to the Courrières system had been adopted in Cumberland for the last 30 years.

Mr. Allan Greenwell (London) said that he had visited the pits at Courrières, and the impression he got was (1) that the roof was very bad (much worse in fact than the report of the four inspectors of mines would lead any one to imagine); and (2) that their method of timbering and using advanced bars was probably the only method by which they could work the colliery. He had no hesitation in saying that if such a roof occurred locally in any colliery in this country a similar method would be, and had been, adopted; and further, if supposing at any colliery in this country such a condition was general instead of local, the colliery would be closed as not being workable to profit. The average cost of timber was said to be 8½d. per ton, but the fact was not mentioned (of which he was assured, when he was at Courriéres) that the cost of getting the coal, including the setting of timber, was only 80 centimes, or about 8d. per ton; and this low cost enabled the owners to protect their ways and roof in such a manner as could not be economically done in this country. There was no doubt that if safety was the sole consideration, it would be possible to tunnel-line all the roads and working-places, but if it were done it would be absolutely impossible to work coal at such a price as would enable them at any rate to compete with America, which was beginning to supply us with coal.

The President suggested that the four inspectors of mines should be invited to inspect the Northumberland collieries, where the death-rate was exceptionally low, and perhaps they would then recommend the methods there adopted.

Mr. C. H. STEAVENSON (Redheugh) said that the members might receive the report of the four inspectors of mines as an interesting collection of facts referring to special methods of timbering under special circumstances, but the system was not applicable to collieries in the North of England, and could not be generally adopted.

Mr. T. A. SOUTHERN (Cardiff) wrote that he thought it was unfortunate that the question of systematic timbering had been brought forward coupled with the special method of timbering used at the Courrières collieries, because that method was a most exceptional one and its adoption in this country would require a drastic change, in fact, quite a revolution, and would cause greatly increased expense. Although the Courrières system deserved most careful consideration from all who had to deal with bad roofs, that system was a much more expensive one than was at all necessary in the majority of British coal-mines, and he was afraid that the mere suggestion of such a revolution and such heavy expense being enforced by law would rouse strong opposition against the mere principle of systematic timbering in any shape or form, and would thus retard progress in this matter, perhaps for many years to come. It would be much better to separate the advocacy of systematic timbering entirely from the Courrières or any other system. The desired object was to get the principle of systematic timbering recognized and applied to the same methods of timbering as those with which our workmen and officials were familiar and experienced. There was room for a great deal of progress in the prevention of accidents from falls of roof in our mines, without going abroad for examples.

Systematic timbering implied the use of definite Special Rules or written instructions drafted by the manager, stipulating how the roof and sides are to be timbered, and the maximum distances apart between the timbers which should not be exceeded. He (Mr. Southern) pointed out that so far as sprags or holing-props were concerned, systematic timbering had been in force since 1887, under General Rule No. 22, and that rule applied to every colliery in the United Kingdom. Also there were several large collieries in this country where systematic timbering and systematic supporting of the roof and faces of longwall workings

had been in force for many years, in various combinations of props and lids, props and bars, cockers, packs, etc., and where definite written orders dealing with this matter were prescribed by the manager, and strictly enforced by the officials, and he thought that no manager, who had once adopted such a system, would wish to abandon it. He believed that it was equally approved by all workmen and officials who had had experience of it.

The opposite of systematic timbering was the haphazard or "prop-where-you-please" style without any regular system: leaving each individual workman and official to use his own discretion and judgment, to set timber only where he thinks that it is needed and to leave it out where he thinks that it is not needed; and also to wait if he likes until the roof seems to him unsafe before setting the timber; in fact, it was practically founded upon the principle of waiting until the roof was unsafe or was approaching unsafeness before setting timber to support it. Of course, on that method, or rather (he should say) want of method, there was a constant running of avoidable risks, there were many accidents due to errors of judgment, and, in a way, the setting of each individual prop was a matter for discussion and argument. They would find wide differences of opinion between any two men, even though both of them had long experience, as to whether a place needed timbering or not, and as to how much timber it did need. On the other hand, systematic timbering gave the colliery-manager and his officials far more effective control over this important part of the work at the working-faces.

Speaking from his own experience, having inspected many collieries with systematic timbering in force, and many more without it, he (Mr. Southern) was strongly in favour of the former, but there should not be one hard-and-fast rule for all seams and all collieries. The details should be fixed by the manager to suit each different district of workings in each seam of each colliery, and the manager should be at liberty at any time, on giving proper written notice to his workmen and officials, to alter the details, whenever required, to meet changing conditions if the roofs and sides become better or worse as the workings extended. And he supposed that there would be no objection to some provision being made, similar to that which already existed in connection with our Special Rules but which was rarely brought into operation, to empower H.M. inspector of mines or the workmen to

object to any such rules or to propose any alteration or amendment of them. It ought always to be made clear that the object of such rules was simply to stipulate the minimum quantity of timber to be set, and the maximum distances apart; that as much more timber must be set as was necessary; and, therefore, whenever a workman was ordered by an official to set more timber than the rules required, he would have to set it, and if he failed to do so it would be a breach of the Special Rule enforcing obedience to orders. It was essential to have this made clear, because such rules must, of necessity, be made to suit the general average condition of the roof in a certain district of workings, and at any time there might be a place where the roof was exceptionally bad, for which the rule or instruction in force would not suffice.

He did not advocate systematic timbering for those working-places which at present required no timber whatever, or almost none, as for instance, narrow places with a strong roof and sides, but in all working-places where timber was generally required he would have systematic timbering fixed by the management of the colliery; and this was most important and necessary for longwall faces and in taking out pillars, because the timbering of roadways was already as a rule under direct official control, even in mines where the timbering at the faces was left entirely to the discretion of the workmen.

A set of rules for systematic timbering should stipulate the minimum length and thickness of the lids and bars to be used, and the minimum thickness of the props; each working-place, in the district to which those rules apply, should be kept furnished with a plentiful supply of loose timber of not less than those minimum sizes; and the rules, besides fixing the maximum distances between the props (measured across and along the longwall face-road respectively) should fix a maximum distance between the props and the face. A most important advantage of systematic timbering was that not only was the roof to be timbered on a certain system, but directly the miner had advanced the face far enough to set his next prop or bar, he must set it at once; there must be "no waiting till the roof was bad." The rules should also specify at what stage of the workings the back timber must be withdrawn.

He (Mr. Southern) gave the following details taken from some large collieries in South Staffordshire, where systematic timbering

had been in force at the faces in every seam for the last 30 years, and was approved by both officials and workmen. In one of the seams, 5 feet to 6 feet thick, with a tender roof and worked by longwall, using props 6½ inches to 7 inches in diameter, and lids 2½ feet long by 6 inches square, two rows or ranks of props and lids are always maintained along the stall-face, except, of course, where the packs (by being built within a few feet of the face) require that a prop, which would otherwise be enclosed and buried in the pack, be withdrawn before topping the pack to the roof. In this seam, the rule is that the props shall be placed not more than 6 feet apart, centre to centre, from prop to prop, measured across the face-road; and not more than 4 feet apart, centre to centre, measured along the face-road; or briefly 6 feet by 4 feet, namely 6 feet between the ranks and 4 feet between the props in each rank. In another seam varying from 6 feet to 7½ feet in thickness, with a tender roof, the props, 6½ inches to 7 inches in diameter (with shorter lids, cut from broken props) are set not more than 5 feet apart, centre to centre, between the ranks, and not more than 4 feet apart, centre to centre, in each rank.

In the Midland mines-inspection district, the Warwickshire coal-field (comparatively small, though it has now about 22 collieries at work with a gross annual output of some 3,000,000 tons and employing about 7,000 persons underground) has had ever since May, 1873 (if not earlier), a Special Rule under which systematic timbering of the stall-faces has been in force. The wording of this rule is as follows:—"The stallmen in each stall shall build efficient packs, and set a sufficient quantity of props, bars, or timber not more than 6 feet apart for safely supporting the roof and sides of their working-places, and shall remove and renew the same when necessary." This means 6 feet by 6 feet, namely 6 feet between the ranks and 6 feet in each rank; but the measurements are made skin to skin, and not from centre to centre. (Centre-to-centre measurements were, however, more conducive to regularity, as props varied in thickness.) So far as he knew, this was the only instance of systematic timbering being in force for a whole county, and he thought that it was preferable to have plenty of elasticity in this matter by having the details adapted by the manager to suit such seam and each district of workings. This was an instructive instance of the recognition of the principle of systematic timbering of longwall faces, and its

enforcement without friction, for at least 28 years, in a score of separate collieries in one county in this country; and, of course, there was nothing in this rule preventing a manager in that county from fixing and stipulating a less distance than 6 feet apart, if he chose to do so.

# THE MINING INSTITUTE OF SCOTLAND.

## GENERAL MEETING,

HELD IN THE ODDFELLOWS' HALL, KILMARNOCK, JUNE 15TH, 1901.

MR. JAMES HAMILTON, VICE-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected by ballot:—

MEMBERS—

Mr. JAMES CURLEY, Poneil Colliery, Coalburn, Lesmahagow.
Mr. HARRY HANNAY, Prospect House, Newton Stewart.
Mr. JAMES HENDERSON, Philpstoun Oil-works, Linlithgow.
Mr. ROBERT SUTHERLAND, Dunbeth Avenue, Coatbridge.

ASSOCIATE MEMBER—

Mr. ARTHUR F. PRICE, 4 West Nile Street, Glasgow.

STUDENT—

Mr. DAVID WILSON, jun., Wester Gartshore Colliery, Kirkintilloch.

Mr. JOHN M. CAIRNCROSS read the following paper on "The South Lesmahagow Coal-field":—

# THE SOUTH LESMAHAGOW COAL-FIELD.*

By J. M. CAIRNCROSS.

The south Lesmahagow coal-field, though situated almost in the centre of Lanarkshire, and within easy reach both of the Ayrshire shipping-ports and the general terminus in Glasgow, is nevertheless comparatively little known, unless to those who are more immediately connected with it. This lack of knowledge is due probably to two causes:—(1) The overshadowing importance of the great Lanarkshire coal-field, whose wellknown seams, both as regards quality and accessibility, leave little to be desired; and (2) to the absence of all literature (if we except the Memoirs of the Geological Survey, and the paper read by Mr. Bryce before the British Association for the Advancement of Science, in 1850) bearing upon the subject.†

Now, however, the Lanarkshire coal-field has probably attained its maximum output, and the better-class seams shew distinct signs of becoming exhausted. It is, therefore, interesting to turn to a coal-field, comparatively close at hand, where there are considerable reserves of coal awaiting extraction. It is true that these coal-seams can hardly be said to take the place of those splendid seams, now on the wane in Lanarkshire; still, for their own particular purposes of steam-raising and gas-producing, these coals are unexcelled, considering the reasonable price at which they are usually sold.

To the geologist and palæontologist, the south Lesmahagow coal-field should be specially interesting, from the fact that here we have three great geological formations practically touching each other, namely:—The Carboniferous, the Old Red Sandstone

* This is called the South Lesmahagow coal-field to distinguish it from the cannel coal-field of Auchenheath, which has usually been termed the Lesmahagow coal-field.

† *Report of the Meeting of the British Association for the Advancement of Science*, 1850, page 77.

and the Upper Silurian, the first and last of these formations being highly fossiliferous. From the point of view of the palæontologist, perhaps the last of the three is the most interesting, from the fact of the many beautiful fossils of crustacea found in this system by its discoverer, the late Dr. Slimon, Lesmahagow.

In speaking of the south Lesmahagow coal-field in relation to that of the Clyde basin, we can only describe it as a patch of Carboniferous rocks about 4 miles long, and 3 miles at its greatest breadth, this area excluding the Ponfeigh and Rigside districts of the Douglas coal-field which are undoubtedly joined to that of Lesmahagow, and whose coal-seams lie on the same horizon. The south Lesmahagow basin has evidently been formed by the deposition of Calciferous Sandstones in a hollow left by the upheaval of rocks belonging to the Old Red Sandstone, and upon the summit of these Calciferous Sandstones, the limestones, ironstones and coal-seams of the Carboniferous Limestone Series were deposited, the limestones and coal-seams probably representing deep water and shallow lagoons respectively.

The Millstone Grit or Farewell Rock of England, if deposited upon the top of these measures, has evidently been swept away by denuding agencies unless at the extreme eastern edge of the field, where it may be said to join that of the Douglas valley.

The thickness of the Carboniferous Limestone Series in this coal-field rarely exceeds 600 feet, and contains in the southern portion eight workable coal-seams, having an aggregate thickness of about 35 feet, interbedded with seams of limestone, ironstone and fire-clay, the first of these being of good thickness and splendid quality. These coal-seams, however, as will be seen later on, do not maintain their thickness as they go northwards, but seem to undergo both a splitting up and a thinning process, which becomes accentuated at the northern extremity of the coal-field. The following sections (Tables I. and II.) taken at Bankend and Auchlochan respectively shew this process in its earlier stages.

The Index or Seven-feet limestone (which derives its name from the fact of its lying immediately above the valuable minerals of the Carboniferous Limestone Series) forms a common base-line or starting-point, by means of which the various seams may be correlated in several coal-fields. We shall therefore proceed to examine them more closely in a descending order.

### TABLE I.—BANKEND SECTION.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Strata | 6 | 0 | 6 | 0 |
| 2 | Index Limestone | 5 | 0 | 11 | 0 |
| 3 | Strata | 30 | 0 | 41 | 0 |
| | *Gas Coal-seam.* | | | | |
| 4 | **COAL** or dross *coal* | 0 | 8 | 41 | 8 |
| 5 | Strata | 24 | 0 | 65 | 8 |
| | *Smithy Coal-seam.* | | | | |
| 6 | **COAL** | 3 | 0 | 68 | 8 |
| 7 | Strata | 6 | 0 | 74 | 8 |
| 8 | **COAL** or dross *coal* | 3 | 11 | 78 | 7 |
| 9 | Strata | 18 | 0 | 96 | 7 |
| | *Glenbuck Four-feet Coal-seam.* | | | | |
| 10 | **COAL** | 3 | 0 | 99 | 7 |
| 11 | Fire-clay | 3 | 6 | 103 | 1 |
| 12 | **COAL** | 2 | 9 | 105 | 10 |
| 13 | Strata | 24 | 0 | 129 | 10 |
| 14 | Blackband Ironstone and *craw coal* | 1 | 11 | 131 | 9 |
| 15 | Strata | 12 | 0 | 143 | 9 |
| | *Nine-feet Coal-seam.* | | | | |
| 16 | **COAL**, stones included | 11 | 0 | 154 | 9 |
| 17 | Strata | 48 | 0 | 202 | 9 |
| 18 | Clayband Ironstone | 0 | 4 | 203 | 1 |
| 19 | Strata | 6 | 0 | 209 | 1 |
| 20 | Clayband Ironstone | 0 | 2½ | 209 | 3½ |
| 21 | Strata | 18 | 0½ | 227 | 4 |
| | *Thirty-inches Coal-seam.* | | | | |
| 22 | **COAL** | 1 | 6 | 228 | 10 |
| 23 | Blaes | 3 | 0 | 231 | 10 |
| 24 | **COAL** | 1 | 0 | 232 | 10 |
| 25 | Strata | 36 | 0 | 268 | 10 |
| | *Six-feet Coal-seam.* | | | | |
| 26 | **COAL**, with 6 inches of stone | 6 | 0 | 274 | 10 |
| 27 | Strata | 60 | 0 | 334 | 10 |
| | *McDonald Coal-seam.* | | | | |
| 28 | **COAL** | 5 | 0 | 339 | 10 |
| 29 | Strata | 30 | 0 | 369 | 10 |
| 30 | Blaes | 12 | 0 | 381 | 10 |
| | McDonald Limestone. | | | | |
| 31 | Limestone | 1 | 8 | 383 | 6 |
| 32 | Blaes | 3 | 6 | 387 | 0 |
| 33 | Limestone | 1 | 8 | 388 | 8 |
| 34 | Strata | 3 | 3 | 391 | 11 |
| 35 | Ironstone | 0 | 8 | 392 | 7 |
| 36 | Strata | 18 | 0 | 410 | 7 |
| 37 | Hawthorn or Main Limestone | 28 | 0 | 438 | 7 |

### TABLE II.—AUCHLOCHAN SECTION.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Strata | 30 | 0 | 30 | 0 |
| 2 | Limestone | 1 | 6 | 31 | 6 |
| 3 | Strata | 12 | 0 | 43 | 6 |
| 4 | Limestone | 3 | 0 | 46 | 6 |
| 5 | Strata | 60 | 0 | 106 | 6 |
| 6 | Limestone | 4 | 8 | 111 | 2 |
| 7 | Strata | 6 | 0 | 117 | 2 |
| 8 | **COAL**, foul | 1 | 0 | 118 | 2 |
| 9 | Strata | 120 | 0 | 238 | 2 |
| 10 | Seven-feet or Index Limestone | 7 | 3 | 245 | 5 |
| 11 | Strata | 24 | 0 | 269 | 5 |
| 12 | **COAL**, foul | 1 | 0 | 270 | 5 |
| 13 | Strata | 42 | 0 | 312 | 5 |
| | *Smithy Coal-seam.* | | | | |
| 14 | **COAL** | 3 | 0 | 315 | 5 |
| 15 | Strata | 1 | 7 | 317 | 0 |
| 16 | **COAL** or dross *coal* | 2 | 6 | 319 | 6 |
| 17 | Strata | 6 | 0 | 325 | 6 |
| | *Ell or Four-feet Coal-seam* | | | | |
| 18 | **COAL** | 2 | 8 | 328 | 2 |
| 19 | Strata | 4 | 8 | 332 | 10 |
| 20 | **COAL** | 1 | 8 | 334 | 6 |
| 21 | Strata | 12 | 0 | 346 | 6 |
| 22 | Blackband Ironstone | 0 | 7 | 347 | 1 |
| | *Nine-feet Coal-seam.* | | | | |
| 23 | **COAL** | 3 | 7 | 350 | 8 |
| 24 | Strata | 6 | 0 | 356 | 8 |
| 25 | **COAL** | 2 | 10 | 359 | 6 |
| 26 | Strata | 36 | 0 | 395 | 6 |
| 27 | Ironstone | 0 | 6½ | 396 | 0½ |
| 28 | Strata | 18 | 0½ | 414 | 1 |
| 29 | Ironstone | 0 | 6 | 414 | 7 |
| 30 | Strata | 6 | 0 | 420 | 7 |
| 31 | **COAL** | 0 | 8 | 421 | 3 |
| 32 | Strata | 24 | 0 | 445 | 3 |
| | *Six-feet Coal-seam.* | | | | |
| 33 | **COAL** | 4 | 6 | 449 | 9 |
| 34 | Strata | 6 | 0 | 455 | 9 |
| 35 | Clayband Ironstone | 0 | 9 | 456 | 6 |
| | *McDonald Coal-Seam.* | | | | |
| 36 | **COAL** | 4 | 0 | 460 | 6 |
| 37 | Strata | 24 | 0 | 484 | 6 |
| 38 | Ironstone | 0 | 5 | 484 | 11 |
| 39 | Strata | 42 | 0 | 526 | 11 |
| 40 | Limestone | 0 | 10 | 527 | 9 |
| 41 | Strata | 7 | 0 | 534 | 9 |
| 42 | Limestone | 1 | 8 | 536 | 5 |
| 43 | Strata | 10 | 0 | 546 | 5 |
| 44 | Limestone | 2 | 0 | 548 | 5 |
| 45 | Strata | 18 | 0 | 566 | 5 |
| 46 | Limestone | 2 | 3 | 568 | 8 |
| 47 | Strata | 24 | 0 | 592 | 8 |
| 48 | Hawthorn or Main Limestone | ... | | ... | |

It will be observed that in the Bankend section, the strata and seams bear a striking resemblance to those of the Muirkirk coal-field as found at Glenbuck; however, in going northwards from Bankend, as already mentioned, the seams display a tendency to split up, thereby giving a larger number of beds, but each of less thickness.

*Index Limestone.*—The Index or Seven-feet limestone is at present only worked by the Poneil Coal Company, near Coalburn Station, though it was worked previously for many years at Auchenbegg, further to the west of the field. It is of the following section, of good quality and sold largely for building, gas-purifying and agricultural purposes:—

| | | Ft. | Ins. |
|---|---|---|---|
| *Roof:* | Blaes ... ... ... ... ... | — | |
| | Limestone ... ... ... ... ... | 1 | 0 |
| *Worked:* | Limestone ... ... ... ... ... | 5 | 6 |
| *Holing:* | Daugh ... ... ... ... ... | 2 | 0 |

In the section, 1 foot of limestone is left for the protection of the roof, the holing or undercutting being done in the 2 feet of daugh.

*Gas Coal-seam.*—Some 30 feet below the Index limestone, there is a gas coal-seam, shewn in the Bankend section, of which a considerable area has been worked by the Bankend Coal Company. No coal from this seam is at present being worked in the district, though a bore-hole near Akertophead on the Auchlochan estate shews a workable section of gas-coal, 1 foot 1 inch thick, which would seem to be on the same horizon, but in some other parts of the Auchlochan estate this gas coal-seam appears to be represented by 1 foot of foul coal.

*Smithy Coal-seam.*—This seam, which is shewn on the vertical section of the Geological Survey as the Ell coal-seam, is, however, known locally by the name of the Smithy coal-seam, while the seam of coal shewn on the vertical section as the Four-feet coal-seam is on the other hand known locally as the Ell coal-seam.

In order to show better the variation of the seams in their extension northwards, sections are given in both Bankhead and

Auchlochan collieries, these collieries being selected in order to retain the same names as those used in the vertical section of the Geological Survey. The sections are as follows:—

| | Bankend. | Ft. In. | | Auchlochan. | Ft. In. |
|---|---|---|---|---|---|
| *Roof:* | Blaes ... | — | *Roof:* | Hard Sandstone ... | — |
| | Smithy Coal ... | 3 0 | | Smithy Coal... ... | 2 8 |
| | | | *Worked:* | Fire-clay, varies in thickness ... ... | 1 6 |
| *Worked:* | Fire-clay ... | 1 6 | | Coal, 4 inches to ... | 1 2 |
| | Wild Gas Coal .. | 0 6 | | Horny ... ... | 0 4 |
| | Dross Coal ... ... | 3 0 | | Dross Coal, 2 feet 2 inches to ... ... | 2 10 |
| *Pavement:* | Fire-clay ... .. | — | *Pavement:* | Fire-clay ... ... | — |

Note.—Horny is a local term for impure gas coal. The holing is made in the dross coal. This coal is supposed to be on the same horizon as a wellknown local deposit in the Auchenheath coal-field, namely, the Wee Gas coal-seam.

In the Bankend district, the bottom seam is worked by inwards longwall, with walls 36 feet wide, and the roads brushed up to the Smithy coal-seam, which is afterwards extracted homewards in the same roads, much in the same manner as the Splint and Virgin seams are wrought in the Blantyre district. This method proves very successful, is cheaply wrought, and gives a small percentage of dross.

In Auchlochan colliery, however (the pits of which are at point C on Plate XI.) this seam is worked both stoop-and-room and longwall, the method of working depending upon the thickness of the top rib of coal—where thin, the longwall method is adopted, but when it increases to about 14 inches, the workings are laid off on the stoop-and-room system, with pillars 60 by 42 feet. At one time, both seams were worked simultaneously in this colliery on the stoop-and-room principle.

This coal is of excellent quality for raising steam and bunker purposes, and is sold principally as "triping."

*Ell or Four-feet Seam.*—The next workable seam in descending order below the Smithy and Dross coal-seam is known locally as the Ell coal-seam though shewn on the vertical section as the Four-feet coal-seam.

The sections are as follows:—

| BANKEND. | | Ft. In. | AUCHLOCHAN. | | Ft. In. |
|---|---|---|---|---|---|
| *Roof:* | Fakes .. ... | — | *Roof:* | Fakes ... ... | — |
| *Worked:* | Fakes, 2 feet to ... | 2 5 | *Worked:* | Horny ... ... | 0 3 |
| | Blacks ... ... | 0 6 | | Coal ... ... ... | 2 7 |
| | Coal .. ... ... | 2 9 | | Fire-clay ... ... | 1 11 |
| *Holing:* | Daugh ... ... | 0 2 | *Holing:* | Coal ... ... ... | 1 10 |
| *Pavement:* | Foul Fire-clay ... | 3 9 | | | |
| | Coal with Horny ... | -- | *Pavement:* | Sandstone ... ... | — |

In Dalquhandy colliery (at letter F on Plate XI.) which may be said to be in the Bankend district, only the top part or half of this seam is worked by longwall, the walls being from 30 to 36 feet wide.

In Auchlochan colliery, more to the north, the fire-clay, having thinned considerably, allows both sections of the seam to be worked together by stoop-and-room, the pillars measuring 60 by 42 feet. A considerable portion of the fire-clay, which is of good quality, is extracted and utilized in brick and pipe-making, and the surplus is built at one side of the road.

A distinguishing feature of this seam is that it has hardly any cleavage, or in other words it possesses neither backs nor cracks, and is in consequence rather hard to get.

This coal is usually sold for locomotive purposes; it is, however, a fair house-coal, and yields an average percentage of dross.

*Splint or Nine-feet Seam.*—About 30 or 40 feet below the Ell coal-seam is found the principal seam of the district, namely, the Splint or Nine-feet seam. This seam lies on the same horizon as the Big Drum seam of the Rigside and Ponfeigh sections of the Douglas coal-field, upon which a paper was read to this Institution some time ago, by the late Mr. Robert Weir.* Owing, however, to the thickening of the metals, it is found there with considerably more strata between it and the Index limestone, evidently shewing that at that part of the field, the water covered the land for a longer period, allowing the thicker deposition of stratified rocks.

The Nine-feet coal-seam is also supposed to be on the same horizon as a coal, 3 feet 3 inches thick, found in the Auchenheath district of the Lanarkshire coal-field, lying between the Wee and Main Gas coal-seams.

* *Trans. Inst. M.E.*, 1899, vol. xvi., page 436.

The sections of the Nine-feet Seam are as follows:—

BANKEND.

| | | Ft. | In. |
|---|---|---|---|
| *Roof:* | Fakes ... | — | |
| | Smithy Coal ... | 0 | 6 |
| | Fire-clay ... | 1 | 0 |
| *Worked:* | Free Coal ... | 0 | 5 |
| | Splint Coal ... | 1 | 4 |
| | Gas Coal ... | 0 | 8 |
| | Coal ... | 1 | 2 |
| | Black Stone, and holing ... | 0 | 5 |
| | Dross Coal ... | 0 | 10 |
| | Horny ... | 0 | 3 |
| | Free Coal ... | 1 | 6 |
| *Pavement:* | Fire-clay ... | — | |

AUCHLOCHAN.

| | | Ft. | In. |
|---|---|---|---|
| *Roof:* | Sandstone ... | — | |
| | Fakes ... | 2 | 6 |
| *Worked:* | Hard Blaes, shaley | 1 | 6 |
| | Blaes ... | 0 | 4 |
| | Dross Coal, left in goaf ... | 0 | 6 |
| | Fire-clay ... | 0 | 3 |
| | Splint Coal ... | 1 | 3 |
| | Gas Coal ... | 0 | 5 |
| | Splint Coal ... | 1 | 0 |
| *Holing:* | Fire-clay ... | 0 | 8 |
| *Pavement:* | Sandstone ... | — | |

This seam is worked by stoop-and-room in the Bankend district, where it is practically all in one section, with stoops about 48 feet square; but in the Auchlochan collieries, where the seam is split up in the thinning-out process previously referred to, only the upper half of the seam is worked, the longwall method being adopted and making a splendid working. The roads are brushed or ripped up to the fakes only in the branches, the main roads being brushed right up to the rock.

This coal is largely sold for illuminating purposes and when sold as such, is filled as "whole seam coal," the gas coal being included. It has been analysed as follows:—

| | | | |
|---|---|---|---|
| Volatile matter ... | | 37·56 | 37·56 |
| Coke: | Carbon ... | 50·45 | |
| | Sulphur ... | 0·20 | |
| | Ash ... | 3·47 | 54·12 |
| Water expelled at 212° Fahr. ... | | 8·32 | 8·32 |

One ton of coal yields on an average 11,355 cubic feet of gas of 22·21 candle-power. Compared with Main Lesmahagow cannel coal represented by 100, and having regard to the value of the secondary products, and the cost of the purification of the gas, this coal is equal to 60, and produces 10·82 cwts. per ton of excellent coke.

This seam has, in a great many cases, especially in the southern end of the field, been cut up by the denuding agency of running water. These instances have been found in both Bankend and

Dalquhandy collieries, where considerable channels have been cut out by these old-time rivers, and afterwards filled up with boulders, water-worn pebbles, sand, etc., causing considerable difficulty in mining operations, owing to the necessity of maintaining a good roof in passing through these wants.

*Six-feet Coal-seam.*—Another very important coal is the Six-feet seam, which is found lying from 84 to 108 feet below the Nine-feet seam, although there is also an irregular seam between these two, called the Thirty-inches, which, however, is not as yet worked in the district. The Six-feet seam is of the following sections:—

| | Bankend. | Ft. In. | | Auchlochan. | Ft. In. |
|---|---|---|---|---|---|
| *Roof:* | Blaes ... ... ... | — | *Roof:* | Blaes ... ... ... | — |
| | Coal ... ... | 1 0 | | | |
| *Worked:* | Free Coal ... ... | 0 5 | *Worked:* | Coal, free ... ... | 1 4 |
| | Stone ... ... ... | 0 2½ | | Stone... ... ... | 0 3 |
| | Free Coal ... ... | 0 10 | | Coal, free ... ... | 0 9 |
| | Stone ... ... ... | 0 2 | | Stone ... ... ... | 0 3 |
| | Free Coal ... ... | 0 3 | | Coal, good ... ... | 0 10 |
| | Splint Coal ... ... | 0 9 | | Gas Coal ... ... | 0 5 |
| | Gas Coal ... ... | 0 6 | *Holing:* | Coal, free ... ... | 0 10 |
| *Holing:* | Free Coal ... ... | 1 8 | | | |
| *Pavement:* | Sandstone ... | — | *Pavement:* | Sandstone ... ... | — |

This seam, like the Nine-feet, is sold principally for locomotive or gas-making purposes. In the latter case, it is sold as "whole seam coal," and in the former it is separated. Large quantities are yearly sold from the district to the Glasgow Corporation, and other gas companies, as second-class cannel, and it produces very good gas at a reasonable cost. An average analysis is as follows:—

| | | |
|---|---|---|
| Volatile matter containing 0·52 of sulphur ... | 39·60 | 39·60 |
| Coke: Carbon ... ... ... ... ... | 46·83 | |
| Sulphur ... ... ... ... ... | 0·21 | |
| Ash ... ... ... ... | 6·94 | 53·98 |
| Water expelled at 212° Fahr. ... ... ... | 6·42 | 6·42 |

One ton of coal yields on an average 11,265 cubic feet of gas of 28·13 candle-power; compared with Main Lesmahagow cannel coal represented by 100, and having regard to the value of the secondary products, and the cost of the purification of the gas, this coal is equal to 72·08. It yields 10·79 cwts. of coke per ton, which is, however, only of medium quality.

It is worked by stoop-and-room in both districts, with pillars 48 feet square near the outcrop, but 72 by 90 feet in the deeper parts of the field. It possesses a difficult roof, which in many cases will not allow of all the coal being extracted. This seam lies on the same horizon as the famous Lesmahagow cannel coal.

*McDonald Coal-seam.*—The lowest workable coal in this field is the McDonald seam, which has a thickness of from 4 to 5 feet.

This coal is so sulphurous and dirty in the Muirkirk coal-field, as to be unworkable; it is, however, believed to be of a workable quality in this district, but includes two bands of stone.

Some of these seams, notably the Nine-feet coal, have been wrought in the district for upwards of 130 years at the extreme south of the field where the outcrops were plentiful. At Bankend, where this coal was worked about the time mentioned, the farmers were in the habit of coming from Crawfordjohn, about 12 miles off, and carrying it away in creels on horseback.

A few years ago, some old workings were discovered and explored upon the farm of Stackhill in the Nine-feet seam, the stoops or pillars being from 4 to 5 feet square and the rooms or stalls from 6 to 7 feet wide. Only the top half of the seam from the dirt position upwards, had been worked, the coal having evidently been wheeled out in barrows. However, until the opening of the Caledonian railway, in 1857, the total quantity of coal extracted must necessarily have been very small, as the ironstone was the great magnet that opened up the coal-fields in these days.

Both clayband and blackband ironstones have been found and worked in the south of the field, especially in the Bankend and Auchlochan estates. For many years after the discovery and exploiting of the clayband ironstone the blackband ironstone was believed to be absent. Some 54 years ago, however, this famous and wellknown stone was also discovered in the district, by Mr. William Forrest, of Brockley farm, for many years a contractor under the Monkland Iron and Steel Company.

The discovery of the blackband ironstone was made through an extensive fall taking place in the clayband seam, which exposed another bed of ironstone higher up: this, on investigation, proved to be the famous blackband ironstone. It averaged about 7 inches

in thickness, was of splendid quality, and had a rib of coal which varied from 4 to 5 inches thick immediately above it, which helped to burn the stone.

The total quantity of ironstone dispatched from this locality between January, 1857 and January, 1863, amounted to 80,000 tons or upwards of 13,000 tons annually. No ironstone, however, is at present being worked in this field owing to the fact that it cannot be produced at a price sufficiently low to enable it to compete with foreign ore; indeed, it is very doubtful if any will ever be worked in future, as the Nine-feet workings immediately below, will in all probability have ruined the stone.

The Mountain Limestone, or *Productus*-limestone, has been wrought for many years at the northern end of the field, and was also formerly worked at Bankend, where it varies from 30 to 50 feet in thickness. This limestone is of great importance and interest to the geologist, being the lowest important recognizable stratum of the Carboniferous Limestone Series. It is of great extent and value, and by analysis has been ascertained to contain:—

| | |
|---|---|
| Carbonate of Lime ... ... ... | 94·40 |
| Carbonate of Iron ... ... ... | 2·22 |
| Phosphates ... ... ... | 0·58 |
| Organic Matter ... ... ... | 0·60 |
| Silica ... ... ... ... ... | 2·20 |
| Magnesia ... ... ... ... ... | a trace. |

The limestone is also known as the Main or Hawthorn limestone.

There is again a nodular limestone, a well defined local deposit, below this, nearly encircling the field and especially well developed on its western and southern margin; it has been traced from the slopes of the Hagshaw hills, as far as Monkshead near Glenbuck. Should it continue to pass round the rising ground at Glenbuck, it would form the connecting-link between the Lesmahagow and Ayrshire coal-fields. The maps, however, of the Geological Survey shew a narrow neck of Old Red Sandstone as the dividing-line between these two fields. Accepting, then, the Geological Survey mapping as correct, we find that the southern Lesmahagow coal-field is flanked on all sides by rocks of Old Red Sandstone age, with the exception of the eastern side towards the Douglas valley, where the seams lie at a much greater depth, owing to the deposition of the Millstone Grit.

At the northern end of the field, about 1 mile south of the village of Lesmahagow, a well defined series of Carboniferous rocks marks its extremity in that direction, and separates it from the Lanarkshire coal-field by a neck of Old Red Sandstone rocks, about 2 miles broad, upon which the village is situated. The seams of the southern Lesmahagow coal-field, though on the same horizon as those in the Auchenheath district on the northern side of this ridge, bear nevertheless no resemblance to each other, and must have been formed under very different conditions. Even allowing that a few feet of strata in the vertical section represents a difference of thousands of years, this would not altogether account for the lack of uniformity in the seams.

It is therefore clear that the only inference that can be drawn by examining the two vertical sections of the Bankend and Auchenheath districts, is that the land must have been elevated and depressed a greater number of times in the southern field, in order to allow of the favourable conditions suitable to the structure and formation of the various seams of coal. From this it may be inferred that the southern Lesmahagow coal-field was more of the nature of a lagoon or shallow sea than the other, and possibly fed the deeper waters with deposits of fine vegetable mud which went to form the famous cannel coal.

The southern Lesmahagow coal-field would appear from present information, to form a basin, having a common centre towards which the seams dip, at or near the northern end of Auchlochan estate, near, or a little further north than D, shewn on Plate XI. At the same time, it is possible that there is an anticlinal axis running parallel with the Caledonian railway, or north and south, past Newfield inn, from which the beds dip eastwards towards the Douglas valley.

So far, nearly all the developments have taken place at the southern extremity of the field, although the centre of the field is comparatively well known by means of bore-holes which are shewn on the 6 inches maps of the Geological Survey.

That the seams extend to the northern margin of the field at a workable thickness, though thinner than they were in the Bankend and Auchlochan district, has been proved at a small colliery sunk by Messrs. W. & R. Waddell, of Aulton lime-works, at A on Plate XI., where a workable seam of good coal has been got at a

depth of 66 feet. From this seam, a bore-hole has been put down to a total depth of 234 feet, proving several workable seams, but owing to the absence of either of the limestones it is difficult to correlate them with those of the Auchlochan district. The following is the entire section found in this pit and the bore-hole:—

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. | No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Moss | 13 | 0 | 13 | 0 | 24 | Fakes | 22 | 9 | 167 | 3 |
| 2 | Gravel and sand | 33 | 0 | 46 | 0 | 25 | COAL, free | 2 | 1 | 169 | 4 |
| 3 | Sandstone | 27 | 3 | 73 | 3 | 26 | Fakes | 5 | 11 | 175 | 3 |
| 4 | Blaes | 6 | 1 | 79 | 4 | 27 | COAL, free | 2 | 0 | 177 | 3 |
| 5 | Sandstone | 2 | 3 | 81 | 7 | 28 | Sandstone | 12 | 4 | 189 | 7 |
| 6 | Do., hard | 4 | 9 | 86 | 4 | 29 | Fakes and fire-clay | 2 | 0 | 191 | 7 |
| 7 | Fakes, dark | 6 | 9 | 93 | 1 | 30 | Sandstone | 1 | 0 | 192 | 7 |
| 8 | Blaes | 24 | 0 | 117 | 1 | 31 | Fakes and fire-clay | 3 | 6 | 196 | 1 |
| 9 | Sandstone | 2 | 9 | 119 | 10 | 32 | Sandstone | 7 | 0 | 203 | 1 |
| 10 | Blaes | 4 | 3 | 124 | 1 | 33 | Fakes | 9 | 0 | 212 | 1 |
| 11 | COAL | 2 | 2 | 126 | 3 | 34 | Blaes | 4 | 6 | 216 | 7 |
| 12 | Fire-clay | 1 | 7 | 127 | 10 | 35 | Ironstone | 3 | 0 | 219 | 7 |
| 13 | COAL, free | 2 | 0 | 129 | 10 | 36 | Blaes | 0 | 6 | 220 | 1 |
| 14 | Fire-clay | 1 | 2 | 131 | 0 | 37 | Ironstone | 0 | 4 | 220 | 5 |
| 15 | Fakes | 0 | 6 | 131 | 6 | 38 | Blaes | 2 | 0 | 222 | 5 |
| 16 | Fakes | 4 | 0 | 135 | 6 | 39 | Sandstone | 4 | 8 | 227 | 1 |
| 17 | COAL, gas | 0 | 5 | 135 | 11 | 40 | Fakes and blaes | 13 | 9 | 240 | 10 |
| 18 | Fakes | 1 | 2 | 137 | 1 | 41 | COAL, soft | 1 | 0 | 241 | 10 |
| 19 | Ironstone | 0 | 6 | 137 | 7 | 42 | Fakes | 0 | 6 | 242 | 4 |
| 20 | Shale | 0 | 5 | 138 | 0 | 43 | Sandstone | 2 | 9 | 245 | 1 |
| 21 | COAL, free | 1 | 3 | 139 | 3 | 44 | Fakes | 1 | 6 | 246 | 7 |
| 22 | Fakes | 4 | 7 | 143 | 10 | 45 | Blaes, dark | 4 | 0 | 250 | 7 |
| 23 | COAL | 0 | 8 | 144 | 6 | 46 | COAL, free | 3 | 8 | 254 | 3 |

A careful comparison of the above strata with those in the vertical section issued by the Geological Survey for Auchlochan district, seems to shew that the most likely correlation is for the last seam shewn in the bore-hole to be the Six-feet seam. The first proof of this, is that the roof-beds of both correspond, namely, first fakes and blaes, and above that sandstone, while we require to go up between 70 and 80 feet to reach the next seam, namely, the Nine-feet, against 84 feet between the same seams in the Auchlochan district. The next distance between the seams, 24 feet, also corresponds. It would therefore appear that here we have the Auchlochan seams dwindled down to about 12 feet of workable thickness, against 30 feet for the same seams at the extreme south of the field. Messrs. Waddell worked only the top seam, which is found dipping gently to the south-east at an inclination of 1 in 12.

The strata are rather heavily watered in this district, and the seam was very subject to rolls in the roof, locally known as "ghosts," which entailed considerable expense in cutting through them.

Probably a large fault, a downthrow to the south, intervenes between this colliery and the most northerly bore-hole on the Auchlochan estate, where the Nine-feet seam is got at a depth of 504 feet: otherwise it is difficult to account for the seams at this point being found so near the surface.

Another proof, if proof were needed, of the continuity and extent of these seams, is the presence of the remains of an old shaft near Newfield or Star inn (B on Plate XI). This pit has been long abandoned; but from the massive stone seat (evidently used for an atmospheric engine) still remaining, it would appear to have warranted even more than the expenditure usual in those days, and would probably be abandoned owing to the rise coal becoming exhausted, and the water when they pursued the coal to the dip becoming too heavy for the antiquated appliances then in vogue for dealing with it.

Again at the east of the field, where it may be said to join that of the Douglas valley, a bore-hole was put down on the farm of Crowhills to a depth of 810 feet, cutting the Auchlochan seams in the last 210 feet, which, however, were here thin and poor. The extra depth here is due to the bore being on the eastern or downthrow side of the large fault, which deposits the Millstone Grit on the top of the Carboniferous Limestone Series. Another bore-hole was put down to an even greater depth near Douglas station, but the seams cut through were again thin and poor.

Coming to the opposite or western side of the field, we find some coal-seams, one of which is supposed to be the Six-feet cropping out in Nethan Water, while a bore-hole some little distance to the south of Akertophead shews several seams of workable thickness.

From the foregoing facts the approximate area and extent of this field may be ascertained, as well as the approximate thickness of workable coal. A very conservative estimate would give a proved area of coal-bearing strata of about 3,000 acres, and assuming the aggregate thickness of workable coal at 20 feet, this would give approximately 57,000,000 tons as the total quantity of coal in the field still to work, an allowance of 15,000,000 tons being made for coal already extracted. This estimate has been based on the assumption of an imaginary line, separating the southern Lesmahagow and Douglas coal-fields, running from

Newfield inn almost due south; and the quantities are calculated on the basis of 100 tons per acre per inch in thickness. This estimate is probably well within the mark.

Owing to a large area of the field being totally obscured by alluvial deposits, such as peat, moss, etc., a knowledge of the faults and dislocations is limited practically to the southern end of the field, where ample scope for study is afforded by the water courses and ravines, many of which display magnificent sections of strata. It is not, however, by any means excessively troubled, although there are a number of faults, varying in throw from 60 to 300 feet, and running generally in a south-easterly and north-westerly direction in the Bankend and Dalquhandy districts. It is difficult to specify any of these, owing to the lack of surface points which would enable one to identify them. Suffice it to say that these faults are not so serious a detriment to mining operations in this part of the field as might have been supposed, as the seams, being for the greater part comparatively shallow, are easily reached by new sinkings when cut off by a fault; while, with the number of seams working, it often happens that the throw of the fault is just sufficient to place one seam opposite another. There is, however, one of these faults crossing the railway at almost right angles near Coalburn station, and passing through Lime-row and south of Middlefield: this fault has a downthrow to the south of about 180 feet. Another fault is found about ¾ mile further north passing the farm at Muirburn, and having a downthrow to the south of between 240 and 300 feet; while another large fault is seen to the east of the field, with a downthrow in that direction, and thereby bringing on the Millstone Grit.

The output from the entire field does not at present greatly exceed 2,000 tons per day, but with developments in progress, and projected, this total is likely to be exceeded in the near future. This output is, however, being raised by the following collieries.

*Auchlochan Colliery.*—This property, which is a very extensive one, was about 1853 leased to Messrs. Addie & Rankine of Langloan ironworks, passing from them through the hands of Mr. J. P. Kidston, Messrs. Colin Dunlop & Company, etc., but

is now being energetically developed by the Caprington & Auchlochan Colliery Company, whose pits are situated at letter C on Plate XI. There are at present three winding-shafts, and another in process of sinking, while arrangements have also been made to sink and equip two large winding-shafts about ½ mile to the dip of those already working. These new shafts will command a very large area of coal, and should be of great service in proving the centre of the field, which is at this point totally obscured by alluvial deposits. These proposed sinkings are shewn at letter D on Plate XI. Owing to the present workings being comparatively close to the southern boundary of the field, large quantities of surface-water find their way into the workings, especially during the winter season. To meet this, a Barclay pump, with cylinders 52 inches in diameter and 8 feet stroke, has been erected, the pump-plungers being 19 inches in diameter with a stroke of 10 feet. The colliery is ventilated by means of a Guibal fan, 25 feet in diameter, running at 40 revolutions per minute. There is also a brickworks in connection with the colliery, where the fire-clay from the workings is made into bricks and pipes.

*Bankend Colliery.*—This colliery, now known under the name of Sitehill, was worked for some years by the Bankend Coal Company, but it is now being developed by the United Collieries, Limited. The principal source of output is some considerable distance from the main line of the Caledonian railway, the coal being conveyed to it by means of a very extensive endless-rope haulage. The haulage-engine has one cylinder, 14 inches in diameter by 3 feet stroke, and geared 3 to 1: the force of gravity of the loaded tubs is, however, in favour of the engine. The rope, of Lang lay, is about 2½ miles long and ⅝ inch in diameter.

Near No. 8 pit is one of the finest coal-outcrops to be seen in Scotland, the Six-feet and other seams being exposed for a distance of several hundred feet in the Hagshaw burn. The ventilation is produced by means of a Guibal fan, 12 feet in diameter, enclosed in an iron casing, and running at 96 revolutions per minute.

*Bellfield Colliery.*—This leasehold is situated on the eastern side of the Caledonian railway, towards the southern extremity of the field, the pits being at point E on Plate XI. It was

formerly worked for some years by the Monkland Iron Company, until taken over by Messrs. William Barr & Sons. There are at present two winding-shafts, by means of which the Dross, Ell, Nine-feet and Six-feet seams are being worked. These seams are almost on the same level as those of Auchlochan colliery, and consequently do not vary much from the sections given. In No. 4 pit, an electric pump has been installed, having three rams, each 7 inches in diameter by 9 inches stroke, discharging water through 2,000 feet of 5 inches tubes against a head of 390 feet. This installation is also pumping from the interior of the workings with satisfactory results. The surface-arrangements include jiggers, picking-tables, washer, etc.

*Dalquhandy Colliery.*—At Dalquhandy colliery, a little to the south of Coalburn (marked F on Plate XI.), are three winding-shafts, working the seams previously mentioned, which at this colliery are more similar to the Bankend than to the Auchlochan section. This leasehold, like the others in the district, is very extensive, amounting approximately to 1,000 acres, and as the coal is in many cases worked to the outcrop, a considerable quantity of surface-water has to be contended with in the workings, especially in the winter season. To meet this difficulty, Messrs. Waddell & Son have installed a double-acting Tangye pump, with 9 inches rams, delivering into one common rising main, while at another pit there is a set of 12 inches bucket-pumps. The colliery is fitted with the usual screening-plant, washer, etc.

*Poneil Colliery.*—Lying between Bellfield colliery on the north and Bankend or Sitehill collieries on the south is Poneil colliery, shewn at letter G on Plate XI. The colliery is being developed by the Poneil Coal Company and is working the Seven-feet or Index limestone as well as the Smithy, Dross, Ell and Six-feet seams, the two latter being worked by the stoop-and-room system. This colliery is fitted with the usual jiggers and picking-tables. It is ventilated by a fan of Guibal type, 12 feet in diameter.

At the extreme northern end of the field, are two limestone-pits, worked by Messrs. W. & R. Waddell and Mr. John Williamson respectively, the bed worked being the Main or Mountain limestone, which is of splendid quality and commands a ready sale for all purposes. The supply is practically unlimited.

From the foregoing remarks it will be seen that there is considerable scope for development in the southern Lesmahagow coal-basin, and the next decade is likely to witness an even greater increase in output, and a greater advance in equipment and washing-plants than that which has taken place during the last.

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Mr. R. W. DRON (Glasgow) said that the members were all indebted to Mr. Cairncross for his paper containing so many carefully worked-out details, as there were many geological features in this coal-field which were certainly of very great interest. Boring operations which had been made near Douglas railway-station had shown that the coals there were very thin, and were considered unworkable. The details in connection with these operations would be most interesting if placed on record. He remembered speaking to a very old man who informed him that the coal-seams on the north-western side, near the Star inn, were also very thin, being not more than 4 feet thick, and of poor quality. A number of bore-holes had also been put down at the north-eastern side of the coal-field, and the same thin seams seemed to be found there.

Further discussion on the paper was adjourned.

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## DISCUSSION OF DR. C. LE NEVE FOSTER'S PAPER ON "METHODS OF PREVENTING FALLS OF ROOF ADOPTED AT THE COURRIÈRES COLLIERIES."*

Mr. JAMES BARROWMAN said that the Secretary of State for the Home Department had instructed four of H.M. inspectors of mines (Dr. Foster, Mr. Henry Hall, Mr. W. N. Atkinson and Mr. John Gerrard) to make a personal inspection of the Courrières collieries, in order to see in practical operation the methods adopted for guarding against accidents by falls, and to ascertain the general conditions under which the work was carried on. These gentlemen, in making their inspection, were anxious to assure themselves that the means adopted were adequate to account for the results obtained and to see to what extent the system might be applicable to British mines. H.M. inspectors of mines received from the director of the Courrières collieries statistics of the fatal accidents from falls of roof and sides during

* *Trans. Inst. M.E.*, vol. xx., pages 164 and 209; and vol. xxi., pages 116 and 223.

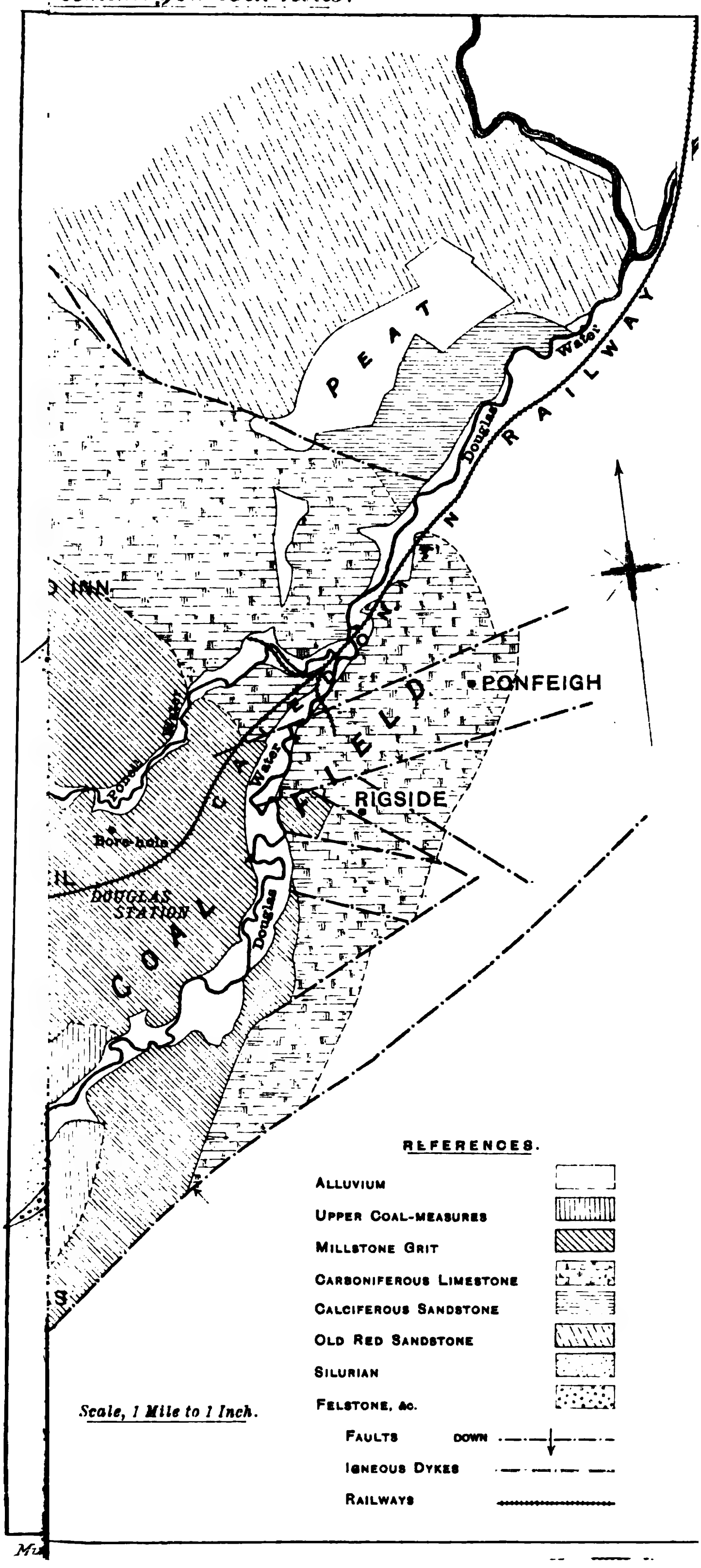
PEAT
Douglas Water
NORTH RAILWAY
INN
PONFEIGH
RIGSIDE
COAL FIELD
Poniel Water
Bore-hole
DOUGLAS STATION
Douglas Water
REFERENCES.
Alluvium
Upper Coal-measures
Millstone Grit
Carboniferous Limestone
Calciferous Sandstone
Old Red Sandstone
Silurian
Felstone, &c.
Faults down
Igneous Dykes
Railways
Scale, 1 Mile to 1 Inch.

TABLE III.—DEATH-RATES FROM FALLS OF ROOF AND SIDE PER 1,000,000 TONS OF MINERAL (MAINLY COAL) RAISED FROM COAL-MINES IN GREAT BRITAIN AND IRELAND.

| Year. | Mines-inspection Districts. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | East Scotland. | West Scotland. | Newcastle-upon-Tyne. | Durham. | Yorkshire and Lincolnshire. | Manchester. | Ireland. | Liverpool. | Midland. | North Staffordshire. | South Staffordshire. | South Western. | South Wales. | Averages for Great Britain and Ireland. |
| 1895 | 2·11 | 1·69 | 1·30 | 1·45 | 1·67 | 3·06 | — | 3·02 | 0·97 | 2·28 | 2·79 | 3 12 | 3·50 | 2·11 |
| 1896 | 1·75 | 2·27 | 1·78 | 1·17 | 1·59 | 2·32 | — | 2·98 | 1·42 | 2·59 | 2·22 | 2·43 | 3·25 | 2 03 |
| 1897 | 2·14 | 2·23 | 2·12 | 1·71 | 2·07 | 2·64 | — | 3·05 | 1·34 | 1·88 | 1·55 | 3·10 | 3·27 | 2·23 |
| 1898 | 1·42 | 2 51 | 0·94 | 1·61 | 1·86 | 3·62 | 7·30 | 3·11 | 1·54 | 2·17 | 1·43 | 2·52 | 2·96 | 2·00 |
| 1899 | 1·75 | 1·51 | 1·66 | 1·88 | 1·31 | 2·50 | 15·23 | 2·16 | 1·51 | 2·01 | 1·73 | 1·80 | 2·78 | 1·87 |
| Averages | 1·83 | 2·04 | 1·56 | 1·57 | 1·69 | 2·83 | 4·43 | 2·86 | 1·37 | 2·18 | 1·93 | 2·57 | 3·15 | 2·05 |

TABLE IV.—DEATHS FROM FALLS OF ROOF AND SIDE AT THE COLLIERIES BELONGING TO THE COMPANIES WHICH EMPLOY THE LARGEST NUMBER OF PERSONS UNDERGROUND IN EACH MINES-INSPECTION DISTRICT UNDER THE COAL-MINES REGULATION ACT, DURING THE FIVE YEARS, 1895-1899.

| Number and Name of Mines-inspection District. | | Name of Colliery Company. | Average Number of Persons employed belowground during the 5 Years. | Deaths from Falls of Roof and Side during the 5 Years. | | | Average Annual Death-rate from Falls of Roof and Side per 1,000 Persons employed belowground. |
|---|---|---|---|---|---|---|---|
| | | | | Roof. | Side. | T't'ls | |
| 1 | East Scotland ... | Fife Coal Co., Ltd. ... | 3,026 | 10 | 3 | 13 | 0·86 |
| 2 | West Scotland ... | William Baird & Co., Ltd. | 6,470 | 22 | 6 | 28 | 0·87 |
| 3 | Newcastle-upon-Tyne | Harton Coal Co., Ltd. ... | 3,690 | 9 | 1 | 10 | 0·54 |
| 4 | Durham ... ... | Lambton Collieries, Ltd. | 7,119 | 25 | 5 | 30 | 0·84 |
| 5 | Yorkshire and Lincolnshire | J. & J. Charlesworth, Ltd | 3,520 | 14 | 4 | 18 | 1·02 |
| 6 | Manchester ... | Bridgewater Trustees ... | 2,933 | 10 | 4 | 14 | 0·95 |
| 7 | Liverpool... ... | Wigan Coal and Iron Co., Ltd. | 3,915 | 12 | 1 | 13 | 0·66 |
| 8 | Midland ... ... | Staveley Coal and Iron Co., Ltd. | 3,689 | 8 | 1 | 9 | 0·49 |
| 10 | North Stafford-shire | Shelton Iron, Steel and Coal Co., Ltd. | 1,628 | 2 | 2 | 4 | 0·49 |
| 11 | South Stafford-shire | Cannock and Rugeley Colliery Co. | 1,414 | 1 | — | 1 | 0·14 |
| 12 | South Western ... | J. Lancaster & Co , Ltd | 2,957 | 10 | 4 | 14 | 0·95 |
| 13 | South Wales ... | Ocean Coal Co., Ltd. ... | 6,390 | 16 | 9 | 25 | 0·78 |

TABLE V.—DEATHS FROM FALLS OF ROOF AND SIDE AT THE COLLIERIES BELONGING TO THE COMPANIES EMPLOYING NOT LESS THAN 1,000 PERSONS UNDERGROUND, WHICH SHOW THE LOWEST DEATH-RATES IN EACH MINES-INSPECTION DISTRICT UNDER THE COAL-MINES REGULATION ACT DURING THE FIVE YEARS 1895-1899.

| Number and Name of Mines-inspection District. | | Name of Colliery Company. | Average Number of Persons employed belowground during the 5 Years. | Deaths from Falls of Roof and Side during the 5 Years. | | | Average Annual Death-rate from Falls of Roof and Side per 1,000 Persons employed belowground. |
|---|---|---|---|---|---|---|---|
| | | | | Roof. | Side. | T't'ls. | |
| 1 | East Scotland ... | Lochgelly Iron and Coal Co., Ltd. | 1,254 | 1 | 1 | 2 | 0·32 |
| 2 | West Scotland ... | Summerlee and Mossend Iron and Steel Co., Ltd. | 1,030 | 1 | — | 1 | 0·19 |
| 3 | Newcastle-upon-Tyne | Mickley Coal Co., Ltd... | 1,444 | 1 | — | 1 | 0·14 |
| 4 | Durham .. ... | Londonderry Collieries, Ltd. | 3,367 | 4 | — | 4 | 0·24 |
| 5 | Yorkshire and Lincolnshire | Barrow Hæmatite Steel Co. | 1,217 | 1 | 1 | 2 | 0·33 |
| 6 | Manchester ... | Hulton Colliery Co., Ltd. | 1,332 | 1 | — | 1 | 0·15 |
| 7 | Liverpool... ... | Garswood Coal and Iron Co., Ltd. | 2,023 | 4 | 1 | 5 | 0·49 |
| 8 | Midland ... ... | Linby Colliery Co., Ltd. | 1,034 | 1 | — | 1 | 0·19 |
| 10 | North Staffordshire | R. Heath & Sons, Ltd.... | 1,623 | 1 | 1 | 2 | 0·25 |
| 11 | South Staffordshire | Cannock and Rugeley Colliery Co., Ltd. | 1,414 | 1 | — | 1 | 0·14 |
| 12 | South Western ... | Powell's Tillery Steam Coal Co. | 1,586 | — | — | 4 | 0·50 |
| 13 | South Wales ... | Great Western Collieries Co., Ltd. | 2,073 | 5 | — | 5 | 0·48 |

(1.) The diagrams printed in the extract of the *General Report for* 1899,* which has been distributed among the collieries of this country, fairly represent the timbering as it is done day by day at Courrières, under the worst roofs; and the statistics given in that report are based upon data exactly similar to those relating to the statistics of falls of ground in this country.

(2.) The system of supporting the roof at the Courrières collieries may be divided into two parts, namely:—(*a*) Systematic timbering, with the timber inserted as soon as there is room for it. (*b*) The use of temporary iron bars to support the roof in advance of the last setting of timber until there is room for another setting.

The first-named part of the system may be practised without the second. Both parts of the system necessitate the use of timber bars in all cases. Single posts with a lid or head-tree do not enter into this system at all. The use of temporary iron bars requires that the timber bars must be set parallel to the face of work.

We quite believe that the Courrières system, if rigidly applied, would result in the prevention of a large proportion of the accidents by falls which might otherwise occur. The worse the roof and the greater the liability to falls, the

* *Trans. Inst. M.E.*, vol. xx., page 164.

more valuable the system would prove, and it would further prevent many of the accidents by falls which occur where there is no appearance of danger. The extra cost involved by the adoption of the Courrières system would be repaid in part by diminishing the number of falls, and so saving not only the cost of compensation for injuries, but also the cost of labour for repairs, as many falls occur without any one being injured.

(3.) The immunity from accidents at Courrières is not by any means due to naturally favourable conditions of the roof, but results chiefly from the extreme care taken in supporting it. The Courrières roof which we saw was certainly not good, and the high degree of safety attained is the strongest possible argument in favour of "systematic timbering."

(4.) We agree with the emphatic opinions expressed by the French engineers as to the necessity of enforcing not only systematic timbering, but also the setting of the timber immediately the distance fixed by regulations has been attained.

(5.) We are distinctly of opinion that more supports are fixed at Courrières to support the roof than is generally the case under similar roofs at home.

The President (Mr. James S. Dixon) wrote that the report by four of H.M. inspectors of mines sent to investigate the system of securing the roofs at the Courrières and Lens collieries in France was very complete, but it did not convince him that the systems described were applicable to collieries in this country, unless under very exceptional circumstances. They state that the seams in these collieries are in a highly disturbed state, in many cases folded over so that the roof becomes the pavement, and twisted about at all angles of inclination. His (Mr. Dixon's) experience was that seams in such circumstances exist in a state of high tension, the strata being ready to burst on being relieved by the removal of the coal, and thus making some special mode of protecting the workmen desirable. Happily such circumstances are of rare occurrence in this country, and are limited very much to the disturbed strata in the immediate vicinity of troubles.

The report stated that the average number of persons killed at the Courrières collieries from falls during the last ten years was 0·15 per 1,000 persons employed belowground, as against 0·78 within the United Kingdom. It is further stated that 42 per cent. of the underground workmen are employed in getting coal, and 58 per cent. in preparatory, haulage and other work. Now it is the former class of workmen who are most subject to accidents from falls. In collieries in this district, the proportion of those getting coal is much higher, being about two-thirds or more of those employed. This of course will materially alter the unfavourable contrast given as applicable to the United Kingdom. It is stated in the report that there is very little chance of any-

one being injured by falls on the main roadways,* which bears out the suggestion that he had made. The methods are described of securing the roofs in the roads, and where the roof is very bad in the faces, by light poles being laid from bar to bar.† This seems to indicate that the strata are in a state of tension and ready to burst as before mentioned, a condition which does not generally prevail in this country. The average cost of timber, 8½d. per ton, in dull times would be ruinous to many collieries in this district.

A method similar to that described, of protecting the roof by shoving forward iron bars, has long been practised in this district for undermining falls and passing through fallen places between stoops, but by using wood instead of iron. He was favourably inclined to the use of iron bars for this purpose, similar to those in use at the Lens collieries, as they seem a great improvement on those used at the Courrières collieries.

In response to the recent communications from the Home Office, the coal-masters have agreed to accept the principle of systematic propping, to be modified to suit the requirements of different circumstances and districts, and this meets what H.M. inspectors of mines state, is the main point requiring attention. For the reasons stated it appears that the system of iron bars in the ordinary workings of our collieries is altogether uncalled for.

It is not usual in Scotland to draw timber from the waste of longwall workings, so that there is no object in discussing the methods described for doing this. In the removal of the pillars in stoop-and-room workings, the systems of propping and drawing timber have by experience been reduced to as near perfection as is well possible, and in this we are rather in a position to give, than to take lessons from others. Millions of tons of coal are worked in this way every year, and accidents from falls when drawing trees are extremely rare; so what was formerly a very dangerous operation, has been rendered safe. The reason for this is that in taking a slice off a stoop, a perfect forest of props is set, and these are drawn by means of a hammer and pick from the inside outwards, the men standing among the upright props in perfect safety. No dog-and-chain or other appliance is desirable, and

* *Report of Four Inspectors of Mines*, page 5.

† *Ibid.*, page 6.

any compulsion to have such used would either be a dead letter or create a danger which does not exist at present.

Mr. THOMAS H. MOTTRAM (Glasgow) wrote that the paper by Dr. C. le Neve Foster, read in conjunction with the subsequent report by him and three colleagues, gives a lucid description of the methods of timbering in vogue at the Courrières collieries. Briefly we gather therefrom that the general system provides that there shall be no separate unsupported roof-space in the mine exceeding 3 feet 3 inches by 18 or 20 inches. In some British mines, in roadways for instance, the crown-trees are set close together "skin-for-skin," and the unsupported roof-space in such cases is less than at the Courrières collieries: while in one pit, the roof at the working-face was so bad that flat boards were required to be used, not only to the head of the seam but also in advance of the working-face where the holing was being done on the top. Such instances show that among mines in Scotland the timbering in some requires to be, and is, as thoroughly done as at the Courrières collieries in France.

But as a rule it is not from this class of roof that most of our accidents occur, for the reason that the coal cannot be got without setting the timber to keep the working-place open, but rather where the roof is considered to be comparatively good. Such a roof naturally is apt to engender delay, and without doubt it is to "delay" that many accidents are attributable. The worker "chaps" the roof, and finds it good enough without timbering in the meantime. He continues to work away, extracts more coal which perchance exposes an unseen weakness in the fresh surface exposed; or a "burst" takes place, the roof falls and an accident occurs. The evidence obtained afterwards invariably shows that a few minutes before the accident the roof had been examined and found as strong as a bell. This points to the fact that this delay in setting or carrying forward timber is in many cases responsible for accidents by falls. On this very point he noticed that "the main point requiring attention and the one which in the opinion of the Courrières engineers most largely conduces to the prevention of accidents, is that supports must be put in as soon as there is room, and that under no pretext may the timbering be delayed."* If this question of "delay" were dealt with,

* *Report of Four Inspectors of Mines*, page 8.

the most difficult part of the problem of how to decrease accidents caused by falls would be solved.

There being but little uniformity in the character of the roofs, there can be no absolute uniformity in any rule or rules applying to the different seams, but whatever the limit fixed for setting timber might be, a limit if fixed by a definite rule would assist officials and workmen and would be something to point to and work up to and thereby help the discipline in the mine.

The many recent discussions that have taken place at the meeting of the various mining institutes indicate that much interest is focussed upon the subject of timbering; and it is refreshing to know that in some of our mines results quite as satisfactory as those of the Courrières collieries are to be found. But much can be learned by observing what is being done elsewhere; and he thought that in some cases the temporary bars referred to in Dr. Foster's and Mr. Reumaux's papers (whether of iron or wood) in advance of the permanent timber might sometimes be used to advantage at road-heads to protect brushers, while removing débris from the shot; and in other cases where timber-supports are used close to the coal-head and blasting is carried on. In the former case, it is sometimes difficult to set props, owing to the dirt lying on the pavement, and in the latter props set close to the coal are liable to be blown out.

Mr. James Hamilton said that he did not suppose that the Home Secretary intended that this exact system was to be applied in all collieries, irrespective of their particular circumstances. He thought rather that it was merely an indication of the direction in which H.M. inspectors of mines and the Home Secretary, as their acknowledged head, intended to go in the way of preventing falls from the roof. There was no doubt that H.M. inspectors of mines and the Home Office officials were anxious that some system of timbering should be adopted irrespective of the character of the roof. H.M. inspectors of mines all declared in their reports that it was the good roofs which caused the greater number of accidents through falls. Where the roofs were bad and dangerous, the men took all necessary precautions to safeguard and protect themselves, while where the roofs were good they were apt to be more careless. He might mention that it would be impracticable to adopt the Courrières system where the seams were less than 2

feet in height. Further, this Courrières system could not possibly prevent the falls of coal, which were most fatal in this country. Mr. Mottram had pointed out where the system would be of most use, namely, at the road-heads and for brushing.

The discussion was adjourned.

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## DISCUSSION OF MR. JAMES KEEN'S "DESCRIPTION OF THE SINKING OF TWO SHAFTS THROUGH HEAVILY-WATERED STRATA AT MAYPOLE COLLIERY, ABRAM, NEAR WIGAN."*

Mr. R. W. Dron (Glasgow) remarked that it would be useful if members, who had experience with steam-pumps for sinking purposes, would state whether their experience had been as favourable as Mr. Keen's. He believed that in several instances steam-pumps had not given as satisfactory results as one would desire. In any case he could endorse Mr. Keen's opinion that the plunger-type of pump was much more suitable than a piston-pump, especially if the water was at all gritty. In a recent sinking he was using a Tangye steam-pump of the double-acting bucket-type, and they had experienced great difficulty with breakdowns: so that a sinking which should have been completed in six months had occupied about three times that period.

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## DISCUSSION OF MR. W. HUTTON HEPPLEWHITE'S PAPER ON "THE HEPPLEWHITE TAPERED PIT-PROPS AND BARS."*

Mr. Geo. L. Kerr (Glasgow) wrote that he noted that Mr. Hepplewhite claimed for his method that it was entirely new in mining practice. Now, in the mere use of tapered props there was nothing new, as the same method had been in use for many years in Lanarkshire and other parts of Scotland. He first saw tapered props used in collieries at Hamilton in the workings of the Ell coal-seam. This seam, as is well known, has often a hard and slippery pavement, and does not yield to the prop when

* *Trans. Inst. M.E.*, 1900, vol. xix., page 462.

† *Ibid.*, 1899, vol. xix., pages 8 and 106; vol. xx., pages 214 and 264; and vol. xxi., pages 55 and 113.

the top pressure comes on. It was generally in the second working or stooping, that is, taking out the pillars, that the tapered props were used and where they were of the greatest service, more especially if the seam was inclined to any extent. The props were tapered by the miners themselves, or by the roadsman with the aid of an ordinary hatchet, the length of taper being usually from 6 to 9 inches. This was found to be of great service, even in the setting of the props, for when it was being driven the tapered end usually became a little "bruised," and kept its position better on the hard pavement.

In the paper which he had read before the Mining Institute of Scotland some time ago, mention was made of such tapered props being used under certain conditions; and the date of the paper was anterior to that of Mr. Hepplewhite's patent. There could be no doubt that under certain conditions of roof and pavement, both in stooping and in longwall workings, tapering the props was a distinct advantage, and would prevent the prop from buckling as readily as it would do with a square-cut end. The practice of using tapered props might not be very common, but such props were certainly used as stated and gave good results. In extracting pillars, large quantities of timber must be used, and very often a large percentage of this timber was rendered useless after one setting, by reason of the props buckling or breaking in the centre. Mr. Hepplewhite claimed that the percentage of broken props had been reduced from 25 to 50 per cent. when they are tapered. Whether that was a correct estimate or not he (Mr. Kerr) would not hazard an opinion, but there was no doubt that where tapered props were used in stooping a considerably larger number could be used over again after being drawn from the first setting, and in this way the cost of timber would be reduced.

It would be an interesting experiment if some of the members who were engaged at collieries where pillar-working was going on, and where the pavement was hard, were to make a trial of tapered props and carefully note the results as to efficiency and life of the timber.

Mr. James Hamilton said there was no doubt that tapered pit-props had been in use in Scotland for many years. In a Fife colliery, he had been told recently by the oversman that he was formerly required, by the owner, to carry an axe along with him at

the morning inspection for the purpose of attending to any props that required tapering. The tapering of props was a common enough practice in Fife, and he (Mr. Hamilton) had seen them used elsewhere. The system of tapering pit-props was of very little use for longwall working in Scotland, where they did not practise the methods of drawing props as in England. The only instance in stooping where tapered props might be of use was where crushing was anticipated.

# SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

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GENERAL MEETING,
HELD IN THE UNIVERSITY, BIRMINGHAM, MARCH 4TH, 1901.

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MR. F. G. MEACHEM, PRESIDENT, IN THE CHAIR.

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## THE LATE MR. JOHN LINDOP.

Mr. F. G. MEACHEM moved that a vote of condolence be sent to the family of the late Mr. John Lindop. From the earliest days of the Institute Mr. Lindop had attended meetings and rendered useful service; he was associated with Mr. Henry Johnson, Mr. David Peacock, Mr. Samuel Bailey, Mr. William Farnworth, Mr. J. H. Cooksey, and Mr. Thomas Latham, the founders, a group of early members who have passed over to the majority.

Mr. H. C. PEAKE seconded the motion, which was adopted unanimously.

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The following gentlemen were elected:—

HONORARY MEMBERS—
Prof. BURSTALL, The University, Birmingham.
Dr. OLIVER LODGE, The University, Birmingham.

ASSOCIATE—
Mr. JOHN FOX, Norton Canes, Cannock.

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## SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE UNIVERSITY, BIRMINGHAM, MAY 6TH, 1901.

MR. F. G. MEACHEM, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and Council Meetings were read and confirmed.

The SECRETARY read the following paper by Mr. Francis Olds, on "The Transvaal Mining Outlook":—

# THE TRANSVAAL MINING OUTLOOK.

BY FRANCIS OLDS.

It is of great interest to mining engineers to study the present outlook in the Transvaal, especially as regards the relative state of the mines now and before war was declared. The war has lasted so long a time, and has been carried through at such enormous expense, that people are becoming depressed and take a very gloomy view of the future mining outlook in the Transvaal. Personally, the writer thinks that this view is uncalled for, and is the result of Great Britain entering into the war with too optimistic an estimate of what would be done, and totally unprepared for a stubborn resistance on the part of the Boers. The war has been a terrible struggle for British or Dutch supremacy in South Africa, with the result that the power of the Dutch has been utterly crushed, Great Britain is to-day supreme in South Africa, and will continue so.

The guerilla warfare, now being prosecuted, is annoying, but it cannot last much longer, if stern measures be employed; and

although Boer bandits may do damage to mines in outlying districts, they cannot injure the large mines on the Rand, or materially alter the present general aspect of the mines.

The majority of the mines have not been damaged so much as might have been expected in a country that has been in a state of war for so lengthy a period. The chief fear of the inhabitants of the Rand relates to the probable amount that the Transvaal will be required to pay, in order to cover the expenses of the war. According to the statements of the Chancellor of the Exchequer, it seems probable that the amount which will be demanded from the Transvaal will be £35,000,000 or about one-third of the cost of the war; and the Rand mines will probably have to meet the greater proportion of this war-tax. Assuming that the Transvaal raises a war-tax of £1,000,000 per annum, the mines could meet more than half of this amount, from their savings on dynamite alone. Dynamite was sold at £4 18s. 6d. per case before the war, and it will probably be sold for £2 8s. 6d. per case after the war, a clear saving of £2 10s. per case; and on the basis of 50 working mines using on an average 400 cases per month, this saving would amount to £600,000 annually. The lowering of excessive railway-rates would also aid in meeting the payments of £1,000,000 annually, while other economies which will be effected under British rule, together with the stricter control and greater efficiency of native labour (owing to the better carrying out of laws regarding the drink traffic) should decrease the cost of working the mines. It may be, owing to the enormous quantity of foodstuffs, mining material, coal, etc., that will be required, that all the mines will not be in working order for several months to come, but 1902 should be the best year that the Rand has yet seen, and the mining outlook in the Transvaal for many years to come appears to the writer to be a very bright one.

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The PRESIDENT proposed a vote of thanks to Mr. Olds for his paper, and it was cordially adopted.

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Mr. WILLIAM CHARLTON then read the following paper on "A Method of Working the Thick Coal-seam in Two Sections":—

# A METHOD OF WORKING THE THICK COAL-SEAM IN TWO SECTIONS.

By WILLIAM CHARLTON.

*I. Introduction.*—The system of working the Thick coal-seam of South Staffordshire described in this paper has been practised at the New Hawne Colliery, owned by Messrs. Shelah Garratt and Sons. The author makes his acknowledgments to the owners and to Messrs. W. and J. Chapman, the manager and under-manager respectively, for permission to visit the colliery and for much valuable assistance and information.

The depth of the shaft to the bottom of the Thick coal-seam is 825 feet, and the seam dips southward at the rate of 1 in 12. The Thick coal-seam is made up of a number of seams separated sometimes by a layer of spoil or batt, and where this is absent, by bedding-planes. Differences in the character of the coals and varying series of cleavage-planes also serve to distinguish the individual seams. Table I. contains a section of the Thick coal-seam and its accompanying spoils at the New Hawne Collieries.

The Thick coal-seam is mined in two sections, the top section 14 feet to 15 feet thick, is worked first, with the rock shown in the middle of the section, as a floor, and the bottom section, 15 feet 4 inches to 16 feet 10 inches, is worked subsequently with the middle rock as a roof. An interval of from two to five years elapses between the working of the top and bottom sections.

*II. Working the Top Section.*—The method of driving the headings or roads in the top section is to hole or bannock in the Floors coal, then to cut down at one side and blow up the Brazils and the Tow coal. Figs. 1 and 2 (Plate XII.) are cross and longitudinal sections respectively of a heading. By this method, the Brazils and the Tow coal produce a large percentage of round coal.

*Forming Sides of Work.*—To form a side of work, three or four headings are driven to the boundary, leaving 120 feet of coal between them. These headings are connected by cross-roads at intervals of about 120 feet for ventilation, so that the work practically resembles the pillar-and-stall method of working in its first stage or whole working (Fig. 3, Plate XII.). These headings are driven in the same way as the opening-out headings previously described.

TABLE I.—SECTION OF THICK COAL-SEAM.

| Names of Seams. | Thickness. Ft. | In. | Ft. | In. | Remarks. |
|---|---|---|---|---|---|
| 1. TOP SECTION— | | | | | |
| Roofs ... ... ... | 2 | 0 | | | |
| Batt .. ... ... ... | 0 | 4 | | | |
| Spires or Top Slipper ... | 2 | 10 | | | |
| White Coal or Slam ... | 1 | 6 | | | |
| Floors ... ... ... | 3 | 0 | | | to 4 feet of very inferior soft coal, mixed with batt, and liable to spontaneous combustion. |
| Brazils and Tow Coal ... | 4 | 4 | | | |
| | | | 14 | 0 | to 15 feet. |
| 2 Rock ... ... ... ... | | | 2 | 0 | to 16 feet of rock between Top and Bottom Sections. |
| 3. BOTTOM SECTION— | | | | | |
| Fine Coal ... ... ... | 2 | 3 | | | |
| Veins Coal ... ... ... | 2 | 2 | | | |
| Swan Coal ... ... ... | 2 | 3 | | | |
| Patchels ... ... | 2 | 6 | | | |
| Batt .. .. ... ... | 0 | 1 | | | to 1½ feet. |
| Sawyer ... ... .. | 1 | 6 | | | |
| Slipper ... ... ... | 3 | 0 | | | |
| Batt ... ... ... ... | 0 | 4 | | | |
| Benches ... ... ... | 1 | 3 | | | |
| | | | 15 | 4 | to 16 feet 10 inches. |
| Total .. ... | | | 31 | 4 | to 53 feet. |

When a pair of roads have reached within 24 feet of the boundary, they are connected by a cross-road, which is holed or side-laned out to a width of 24 or 30 feet (Fig. 4, Plate XII.) and an opening is formed, similar to those in "square work." The top coals are got in this opening in the same way as in the "square work" method of working described by Messrs. Clark & Hughes, in their "General Description of the South Staffordshire Coal-field, South of the Bentley Fault,"* namely, by cutting along the rib-side and dropping the top coals in succession,

* *Trans. Inst. M.E.*, 1891, vol. iii., page 25.

by drawing the timber, commencing in the centre of the opening and working back towards the roads.

Whilst this work is in progress, another cross-road, *A*, (Fig. 4, Plate XII.) is being driven across the pillar, so as to cut off a rib of coal, 39 feet wide. This rib is subsequently cut into four pillars, by driving three roads, *B*, *C* and *D*, through it into the back "shutt" or gob (Fig. 5, Plate XII.). These pillars are removed in quarters; starting in the middle road, *C*, the back quarter-pillars, *E*, *E*, (Fig. 6, Plate XII.) are taken out by holing under the coal and drawing the timber. Then dropping back to the cross-road, the quarter-pillars, *F*, *F*, are removed. From the other two roads, *B* and *D*, through the rib, the quarter-pillars, *G*, *G*, *G*, *G*, (Fig. 6) are wrought; from the cross-road, *A*, the quarter-pillars, *H*, *H*, *H*, *H*; and finally from the side-roads, the portions, *I*, *I*, *I*, *I*. At the same time as these pillars are being removed, a fresh cross-road, *K*, is driven, and other pillars cut off to come into work.

*Fires.*—Fires occasionally occur in this work, and in nearly all cases it is due to the heating of the slack of the Floors coal. This seam contains so much batt as to be worthless, and as far as possible it is left in the mine.

*III. Working of the Bottom Section.*—It has already been remarked that an interval of from two to five years elapses after the upper portion of the seam is wrought, before an attempt is made to mine the lower portion. The longer the interval the better, especially where the intervening rock is thin, as time is allowed for the top gob to become consolidated, and for any fires which have occurred to burn themselves out.

*Driving Roads.*—Two methods of driving the bottom roads have at different times been practised. At one time the roads were driven 7 feet wide in the Benches, Slipper and Sawyer coals. These roads, however, do not stand well, as the Sawyer being a weak, tender coal, "ghouls," or wastes, over the top of the Slipper coal, which is strong, and between it and the Patchels which also is a strong coal and forms the roof (Fig. 7, Plate XII.). At the present time, the invariable practice, when forming roads, is to drive the stalls 30 feet wide; wooden chocks, 2½ feet square

and 6 feet apart, are built on the road-sides, and behind and between them is filled with cogging of rock and other débris, not liable to fire, a road being left, 7 feet wide. Figs. 8 and 9 (Plate XII.) are a cross-section and plan respectively of a road. This method has been followed for sixteen years, and in no case has a fire occurred in the back of the pack-walls.

The holing is made in the Benches coal, the Slipper coal is taken down, and chocks and cogs are built up to the Sawyer coal, which is cut down in the roads to make height. The Patchels coal makes a good roof, the Sawyer coal appears to cushion upon the packing and there is a total absence of that "ghouling," which was so objectionable in the fast roads. The cost for timber and repairs is very much less in this than in the former method.

The stalls are ventilated between the spouts, by carrying a small air-way behind one of the pack-walls. These air-ways are tightly gobbed up, when they fall out of use by the driving of another spout (Figs. 8 and 9, Plate XII.).

*Forming Sides of Work.*—In forming sides of work, two roads are driven in the manner just described, 120 feet apart, from centre to centre. On reaching their allotted distance, they are connected by a cross-road, which is holed out for a width of 30 feet (Fig. 10), and an opening, *A*, formed in a way precisely similar to that described as being done in the top working and shown in Fig. 4 (Plate XII.). Beyond this point, the method pursued is different. Previous to dropping the coals, a row of wooden cogs, *B* (Fig. 10, Plate XII.), each 6 feet square is built from 4 to 6 feet from the fast rib-side. At the same time, as the top coals are being dropped in the opening, *A* (Fig. 10), another set of men drop back 12 to 15 feet in each road, and commence holing the coal between the roads, as shown at *C*, *C* (Fig. 11, Plate XII.), and working backwards in the direction of the arrows until a stall, 12 to 15 feet wide and 120 feet long, is formed between the roads. Another set of cogs, *D*, is built, near to the newly formed fast or coal-side. There are now two rows of cogs, one, *B*, next the shutt or gob and the other, *D*, near the rib-side. The top coals are dropped by withdrawing the gob-row of cogs, *B*, and the timber between them and the rib-side cogs, *D*. Small packs of batt or stone are built behind the chocks, and these facilitate their withdrawal. The timber from the cogs

withdrawn is used to build the succeeding row of cogs, built near the fast side when another stall is formed between the roads.

*Fires.*—Little inconvenience from fires is experienced in working the bottom section. The only cases that occur are when working under ribs or pillars that have been left in the working of the top coal. These pillars are ground into fine coal and readily fire when the shutt or gob runs in, consequently the successful working of the bottom section is dependent on the complete extraction of the top portion of the seam in the first working.

*IV. Conclusion.*—It is claimed by the management of New Hawne colliery that by these methods of working (1) practically the whole of the seam is wrought and nothing is left for a second working; (2) the liability to fires is reduced to a minimum; and (3) the cost of timber is very greatly reduced.

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A vote of thanks was accorded to Mr. Charlton for his paper.

Several members stated that the system described by Mr. Charlton had been often tried at other collieries, but it was only adapted for special circumstances, such as those existing at the New Hawne colliery.

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FIG. 1.—

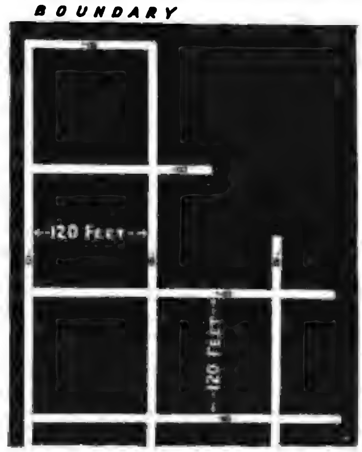


FIG. 3.—PLAN.

*Scale, 200 Feet to 1 Inch.*

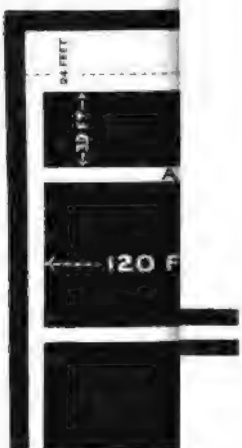


FIG. 4.

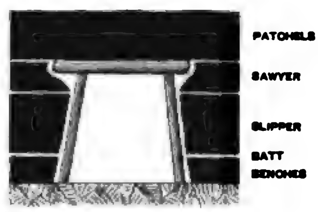


FIG. 7. CROSS SECTION.

*Scale, 10 Feet to 1 Inch.*



FIG. 11.—PLAN.

*Scale, 100 Feet to 1 Inch.*

# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING OF STUDENTS,
BEARPARK COLLIERY, MAY 1ST, 1901.

About 40 students and associates visited Bearpark colliery.

## BEARPARK COLLIERY.

Bearpark colliery is situated in the valley of the Browney, and the Busty coal-seam is being worked at a depth of 396 feet. In the centre of the valley, the Coal-measures have been denuded, and the valley filled up with diluvial and alluvial deposits to a depth of about 150 feet, under which the seam is being worked. The coal is carried by means of travelling scrapers, over screens with bars of various widths, on to picking-belts; and this arrangement deals with the varying conditions of the coal (either wet or dry, small or round) better than shaking-screens, which clog and cause vibration of the heapsteads. The coal after having been cleaned is passed through Carr disintegrators and reduced to small for coking purposes. A separate shaft has been sunk for the purpose of carrying the workmen into and out of the mine, at which the coals from the Hutton seam are drawn.

The coke-yard comprizes two double rows of beehive coke-ovens (which are loaded by small locomotive engines), and a battery of 50 Simon-Carves retort-ovens, and the tar, pitch, ammonia and naphtha are recovered.

Steam is produced from boilers heated by the waste-gases from the coke-ovens, and the exhaust-steam from the principal engines is conveyed to a central condensing-plant worked by an independent engine.

# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

## GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JUNE 8TH, 1901.

MR. J. G. WEEKS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting and reported the proceedings of the Council at their meetings on May 18th and that day.

The SECRETARY read the balloting-list for the election of officers for the year 1901-1902.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. OWEN SALUSBURY BATCHELOR, Mining Engineer, Assayer and Prospector, Kamloops, British Columbia.

Mr. MYLES BROWN, Manager, Shampore Coal Company, Limited, Shampore, Nirshachatti P.O., E.I.R., Bengal, India.

Mr. ALFRED LLEWELLYN FORSTER, Engineer to the Newcastle and Gateshead Water Company, 5, Haldane Terrace, Newcastle-upon-Tyne.

Mr. WALTER JAEGER KOEHLER, Metallurgist, Freemantle Club, Freemantle, Western Australia.

Mr. JOSEPH SEVERS, Colliery Manager, North Walbottle, Newburn, R.S.O., Northumberland.

Mr. ALFRED TENNYSON TYE, Mining Engineer, Gold Hill, Saratoga, Wyoming, United States of America.

ASSOCIATE MEMBERS—

Mr. HERBERT GEORGE FENWICK, Birtley, County Durham.

Mr. THOMAS WILLIAM GIBSON, Director, Bureau of Mines, Toronto, Ontario, Canada.

Mr. H. P. HARRIS-EDGE, Coalport Works, Shifnal, Salop.

STUDENTS—

Mr. JOHN R. FELTON, Mining Student, West Stanley Colliery, Stanley, R.S.O., County Durham.

Mr. MEYRICK PALMER, Mining Student, The Manor House, Medomsley, R.S.O., County Durham.

Mr. TOM R. RIDPATH, Mining Student, Medomsley, R.S.O., County Durham.

## JUBILEE OF THE INSTITUTE.

The SECRETARY reported that arrangements had been made for the celebration of the fiftieth anniversary of the foundation of the Institute in September, 1902, and that the Institution of Mining Engineers had arranged to hold their annual meeting in Newcastle at the same time.

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## DISCUSSION OF MR. E. REUMAUX'S PAPER ON "THE EMPLOYMENT OF IRON BARS AT THE No. 6 PIT, LENS COLLIERIES."*

Mr. H. F. BULMAN (Burnopfield) wrote that Mr. M. Walton Brown had made him responsible for the statement that at the Courrières collieries "the roof is usually shale."† This was not correct, as he (Mr. Bulman) stated that this was the nature of the roof in the working-places of the Sainte Cécile coal-seam at the No. 3 Méricourt pit, visited by him, where "the back timber was being drawn."‡ The colliery officials stated that over the eight coal-seams being wrought, there was a great variety of roof—good, bad and indifferent.

* *Trans. Inst. M. E.*, 1890. vol. xx., page 206; and vol. xxi., page 223.

† *Ibid.*, vol. xx., page 214.

‡ *Ibid.*, page 212.

# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING OF STUDENTS,
SEAHAM HARBOUR, JULY 10TH, 1901.

About 40 students and associates visited the Dawdon and Seaham collieries.

## DAWDON COLLIERY.

Dawdon colliery is situated about 1 mile south of Seaham Harbour.

The Castlereagh or north shaft has a diameter of 21½ feet inside the walling, and will be reduced to a diameter of 20 feet, and has at the present time attained a depth of 187 feet. The shaft is being lined with cast-iron tubbing, to an internal diameter of 20 feet; a wedging-crib was laid at a depth of 132 feet, the foundation-course is 1⅛ inches thick, and there are 15 rings of tubbing, ⅞ inch thick.

The winding-engine has two cylinders, each 24 inches in diameter by 4 feet stroke, the drum has a diameter of 8 feet and a width of 6 feet, and the locked-coil rope is 3¾ inches in circumference, and weighs 27 cwts.

The Theresa or south shaft is 21½ feet in diameter inside the walling, and will have a finished diameter of 20 feet. The depth to the bottom of the wedging-crib is 196½ feet. The winding-engine is of the same dimensions as that at the Castlereagh shaft.

Both of the present winding-engines will eventually be used for underground haulage.

The horizontal pumping-engine, with two cylinders, each 36 inches in diameter by 6 feet stroke, works two sets of pumps 24 inches in diameter, and one set 25 inches in diameter, and runs at 15 to 18 revolutions per minute. There are two Evans vertical sinking-pumps, with cylinders 24 inches and 16 inches in diameter by 24 inches stroke, capable of delivering 1,000 gallons per minute from a depth of 300 feet. The feeder of water at present averages 6,075 gallons per minute. A double-drum steam-winch, capable

of lifting 5 tons direct from each drum, is used for moving the Evans pumps, worked by cylinders, 8 inches in diameter by 10 inches stroke.

The main crab-engine has two horizontal cylinders, 14 inches in diameter by 3 feet stroke, it is geared at 16 to 1, and the crab-rope is 6½ inches in circumference.

The ground crab-engine has two horizontal cylinders, 8 inches in diameter by 14 inches stroke, it is geared at 30 to 1, and the rope is 5½ inches in circumference.

There are six Galloway boilers, 30 feet long by 8 feet in diameter, the furnaces are 3¼ feet in diameter, and steam is produced at a working pressure of 100 pounds per square inch. There are four sets of Green fuel-economizers, each with 120 pipes 9 feet long. The chimney, at present in course of erection, with a base 22 feet square, will have a height of 160 feet, and an inside diameter at the top of 12 feet. It is estimated that the total weight of the chimney will be 1,200 tons, and 360,000 bricks will be used in its construction. The estimated horse-power is 2,930.

The Mather-and-Platt water-softening tanks are each 15 feet 6 inches square by 10 feet deep, with a capacity of 15,000 gallons. The plant is capable of softening 60,000 gallons of water per day, and reduces the hardness from 16 degrees to 4 or 5 degrees. A mixture of 40 pounds of lime and 7 pounds of alkali is used for each charge of 15,000 gallons of water. The cost of treatment is 0·58d. per 1,000 gallons.

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## SEAHAM COLLIERIES.

The Seaham collieries are situated near Seaham Harbour, about 6 miles south of Sunderland. The attached royalty has an area of 5,000 acres, and the output is 2,700 tons per day.

The thicknesses of the seams, now being worked, and their respective depths at the several pits, are as follows:—

| Name of Coal-seam. | Thickness. Ft. | Thickness. Ins. | Depth at No. 1 Pit.* Feet. | Depth at No 2 Pit.* Feet. | Depth at No. 3 Pit. Feet. |
|---|---|---|---|---|---|
| Main ... ... ... | 5 | 0 | 1,309 | 1,309 | 1,306 |
| Maudlin ... ... | 5 | 0 | 1,361 | 1,361 | 1,355 |
| Low Main ... ... | 4 | 4 | 1,428 | 1,428 | — |
| Hutton ... ... | 4 | 3 | 1,530 | 1,530 | 1,506 |
| Flat-sheets .. | — | | 1,530 | 1,686 | 1,506 |
| Bottom of sump ... | — | | 1,800 | 1,800 | — |

* This is one shaft, divided into Nos. 1 and 2 pits.

At the No. 1 pit, the vertical winding-engine has a cylinder, 67 inches in diameter by 7 feet stroke, and the drum has a diameter of 21 feet. This engine lifts a load of 12 tons, consisting of:—Tubs and coal, 4 tons 10 cwts.; cage and chains, 3 tons 10 cwts.; and rope, 4 tons. The depth of this shaft to the flat-sheets is 1,530 feet.

The vertical winding-engine at the No. 2 pit has a cylinder 67 inches in diameter by 7 feet stroke, and the drum is 21 feet in diameter. The depth to the flat-sheets is 1,686 feet, and to the bottom of the sump, 1,800 feet.

The vertical winding-engine at the No. 3 pit has a cylinder, 70 inches in diameter by 7 feet stroke, and the drum is 21 feet in diameter. The load lifted is 14 tons, including:—Tubs and coal, 6 tons; cage and chains, 4 tons; and rope, 4 tons. The depth of the shaft to the flat-sheets is 1,506 feet.

The differences of level between the bottoms of the various shafts and the working districts are as follows:—From No. 1 pit to the face of the straight east district of the Hutton seam, 356 feet; to the lowest point in the straight east district of the east side of the Maudlin seam, 669 feet; and to the highest point in the second north district in the north side of the Maudlin seam, 221 feet. From the No. 3 pit to the highest point of the old north district in the new incline way of the Main coal-seam, 320 feet.

The hauling-engine for the Maudlin seam has two cylinders, each 26 inches in diameter by 5 feet stroke, the drums being 7 feet in diameter. The steam has a pressure of 100 pounds per square inch. The hauling-ropes are carried down the upcast shaft in wrought-iron pipes, 3 inches in diameter. The distance from the bottom of the shaft to the intermediate landing is 5,610 feet, and to the straight east landing, 10,362 feet. In the No. 1 pit, Hutton seam, 60 tubs form a set, and the approximate weight of the tubs and coal is 45 tons; and in the east side of the Maudlin seam, 70 tubs run in the set, the approximate weight of tubs and coal being 52 tons.

The air-compressor has two steam-cylinders, each 44 inches in diameter, and two air-cylinders each 46 inches in diameter by 6 feet stroke. The steam-pressure is 100 pounds to the square inch, and the air has a pressure of 50 pounds to the square inch. There are ten hauling-engines and twelve pumps underground worked by compressed air.

At the No. 3 pit, there are two cleaning-belts, each 80 feet long by 4½ feet wide; and one cleaning-belt, 60 feet long by 4 feet wide.

A Kingston water-softener deals with 6,000 gallons of cold water per hour, a mixture of alkali and lime being used; and the cost for material and labour is about ¾d. per 1,000 gallons of water treated. A Chevalet-and-Boby heater-detartarizer deals with 4,000 gallons per hour, the composition used being alkali; and the treatment costs about ¾d. per 1,000 gallons. Underground, in the No. 1 pit, a Harris heater and softener treats 2,000 gallons of water per hour, the composition used being caustic soda; and the cost per thousand gallons of water treated is ¾d.

The number of workmen employed underground is 1,873, of whom 780 are hewers; and 451 are employed on the surface.

There are 382 horses and ponies employed underground.

# NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,
RUNCORN AND LIVERPOOL, JUNE 26TH, 1901.

## MANCHESTER SHIP-CANAL.

The Manchester Ship-canal Company placed a steamer at the disposal of the excursionists, who numbered about 70. On arriving at Runcorn, the visitors, led by Mr. E. N. Greatbach, were received by Mr. Medicraft, the district agent for the Manchester Ship-canal Company, and Mr. H. Bodington, of the Anderton Company. Explanations were afforded to them as to the relative positions of the Manchester Ship-canal and of the Bridgewater Canal and of the North Staffordshire Railway Company. The visitors inspected the Ship-canal Company's warehouse at Runcorn, used as a resting place for goods during transhipment. There was a large stock of china-clay from Cornwall, and bone-ash from Rio Grande; and a large number of crates of ware for shipment to the United States.

The visitors embarked on board the Manchester Ship-canal Company's steamer St. Winifred, and proceeded westward along the ship-canal to Ellesmere Port. They inspected the warehouses and the junction with the Shropshire Union Canal, which leaves the Mersey at this point and joins the Bridgewater Canal farther inland.

The next stopping place was Eastham locks, within 6 miles of Liverpool. On leaving Eastham, the party had a pleasure-trip on the Mersey to New Brighton.

# NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

## GENERAL MEETING,
HELD AT THE GRAND HOTEL, HANLEY, JULY 15TH, 1901.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were confirmed.

The following gentlemen, having been previously nominated, were elected:—

MEMBER—

Mr. HARRY CAUSTON, Mechanical Engineer, Tunstall.

ASSOCIATE MEMBERS—

Mr. JOHN MITCHELL, Tunstall Coal and Iron Company, Limited.
Mr. H. B. STEELE, Hanley Borough Colliery.
Mr. HUGH WILLIAMSON, Goldendale Ironworks.

ASSOCIATES—

Mr. ROBERT CUMMINGS, Under-manager, Parkhall Colliery, Longton.
Mr. HENRY MOLLINEUX, Alsager's Bank, near Newcastle, Staffordshire.

Mr. J. KENT SMITH read the following paper on "Water-softening":—

# WATER-SOFTENING.

By J. KENT SMITH.

*Introduction.*—In treating the subject of water-softening it is understood that the water is intended for use in the generation of steam, and not for domestic purposes; in the latter case, a different set of desiderata—which would probably materially modify some of the details of procedure—would have to be considered.

It is unnecessary to particularize or to lay stress upon the many deleterious effects of scale, with its concomitant burnt plates and seams, high fuel-consumption, and excessive wear-and-tear and cost of cleaning. The question becomes one of the utmost importance where quick-steaming water-tube boilers are employed, worked at high pressure. As will be seen, the question of pressure, upon which the internal temperature of the boiler depends, is of vital importance to the precipitation of at least one of the scale-forming constituents, and this, in the case of water-tube boilers, is intensified by the extra area upon which scaling may take place. Thus a water which might work satisfactorily in an egg-ended boiler, of the primitive type, steaming at (say) 25 pounds, would prove a hopeless stumbling-block to the working of a modern water-tube boiler steaming at (say) 175 pounds. Then again, the effect of such a water upon the multiplicity of tubes contained in an ordinary fuel-economizer would almost as completely bar it.

*Hardness.*—By the term hardness is generally understood the soap-destroying power of a water, and this is usually accepted as an indication of its scale-forming powers also. But the one does not necessarily follow the other, for if the hardness of a water were principally due to sulphate of magnesia, it might, while still destroying a large amount of soap, be very low in scaling properties. Then again, an equal amount of soap-destroying power might be due in one case to sulphate of calcium, and in the other case to chloride of calcium. In some cases, the writer would regard the latter as the more undesirable of the two, owing to the danger of secondary reactions taking place, as will be described later.

Before going further, it might be desirable to consider the different forms of those constituents which give hardness or scale-forming properties to a water.

*Constituents of Scale.*—Suspended mineral particles almost invariably act prejudicially in a boiler; and in some cases, waters, which contain them and give considerable trouble to steam-raisers, after their removal by the simple process of filtration, are rendered innocuous. The suspended matter, if siliceous, seems to act as a binding agent to any scale that may be formed, and if that scale be formed of carbonate of lime, or still more so if magnesia (hydrate) be a constituent of the scale, it has a tendency to form a true cement in the boiler. If the suspended matter be removed before the entry of the water into the boiler, the tendency towards scaling is greatly reduced, and, furthermore, any scale formed is much more pulverulent, and the matter precipitated is to a considerable extent disposed of by means of the sludge-cock. Of course filtering a water will not do good in every case, although it may possibly be helpful in some cases.

Oily matter, while not adding to the hardness of a water, promotes the formation of a very dangerous and undesirable deposit, and this deposit becomes infinitely more undesirable if it approaches the character of an insoluble soap (*i.e.* if it be due to a vegetable oil). Prof. Vivian B. Lewes has shown before the Institution of Naval Architects* that this deposit is more responsible for the collapse of plates and tubes in boilers at sea than any other. Water drawn from the hot well of a condensing engine, or heated by exhaust-steam is of course chiefly liable to be thus contaminated. In the process of treatment recommended hereafter this oily matter would be mechanically removed.

Of the scaling constituents that also cause hardness, the carbonates of lime and magnesia deserve first consideration. These substances are practically, except to the extent of 2 or 3 grains per gallon, insoluble in pure water, but are soluble in water containing carbonic acid. In cases of hardness arising from this cause (or from the presence of carbonate of iron, which behaves in a similar manner, but which is more uncommon), if the water be boiled the carbonic acid is expelled and the earthy carbonates are precipitated. The hardness is then said to be temporary. But

* *Transactions*, 1889, vol. xxx., page 330; and 1891, vol. xxxii., page 67.

from a commercial point of view, boiling, on the score of expense alone, is out of the question as a means of softening. Yet if we add some substance which chemically removes the surplus carbonic acid, the carbonates are precipitated in the same way. The cheapest substance is lime, preferably added in the form of lime-water. If this addition be made in correct proportion to the amounts of carbonate of lime, magnesia and iron present, they and the added lime itself are thrown down as insoluble salts. Thus we may achieve the apparent paradox of softening a water, whose hardness is due to lime, by the addition of lime to it. Besides removing the scale-forming components of such a water, the lime will do further good in removing the dissolved carbonic acid in that water: carbonic acid having a very marked corrosive action on iron plates. The carbonate of magnesia, if not previously removed, has a tendency to decompose on boiling, giving off carbonic acid, and forming magnesium hydrate, and this body acts as a cement, more especially in the presence of sulphate of lime.

Sulphate of lime is present in nearly all waters, and is not removed by boiling or liming. (Hardness not removable in this way is said to be permanent.) It gives rise to a very troublesome form of scale. It is soluble in ordinary water, even when boiling at atmospheric pressure, to the extent of 150 grains per gallon of water; and even up to about 180 grains per gallon can be dissolved in pure water. This extraordinary substance becomes less soluble as the temperature of the boiling water increases, until at about 300° Fahr. (which is equivalent to a working pressure of about 70 pounds) it becomes completely insoluble. This decrease in solubility can be explained by the fact that the soluble compound is a hydrated sulphate, and as the temperature rises this compound becomes decomposed, the solubility diminishing until the anhydrous salt is reached, which latter is practically insoluble. With one exception, sulphate of lime has been a constituent, and in most cases a preponderating one, of every boiler scale that the writer has ever examined, and as has been previously shown it is especially liable to form a very troublesome scale in the presence of magnesia. There is no chemical action where magnesia and sulphate of lime occur together, but combination gives rise to trouble. Its removal, as will be seen, is unattended by any very great difficulty.

Calcium and magnesium chlorides are not in themselves scale-formers, although they destroy soap, being very soluble in ordi-

nary water; but when water containing them is boiled under pressure, namely, at an elevated temperature, they become decomposed, the hydrates of the bases being formed and hydrochloric acid evolved. Most waters, luckily, contain sufficient carbonates to neutralize this hydrochloric acid; but some cases have occurred where this has not been so, and great corrosion of steam-plates, pipes, valves and pistons has resulted. In the case of calcic hydrate (lime) being formed, it does not do much harm, merely taking up the carbonic acid from the incoming feed and becoming precipitated. Magnesium hydrate however, as we have seen, has some very objectionable properties.

Sulphate of magnesia is a soap-destroyer, but, in all ordinary circumstances, never causes scaling-trouble, and a water whose hardness was chiefly due to this body, while appearing very bad on the soap-test, would give no trouble in a boiler, magnesium sulphate being a very soluble and very stable salt.

The chlorides of sodium and potassium are not soap-destroyers, nor do they give scale, and are not at all likely to give rise to any trouble. In a concentrated solution, however, they would be liable to corrode a boiler-plate, the metal of which contained much manganese.

The nitrates of soda and potash are, to all practical intents and purposes, harmless. These last four bodies would not be removed —in fact, to a small amount they would rather be produced, by treating the water. The sulphates of soda and potash are likewise harmless.

Acid waters occasionally exist, where derived from sources in contact with coal, or near some large towns. They destroy soap in proportion to their acidity, and corrode iron quickly, but in treatment they would be instantly neutralized by the precipitating chemicals employed to reduce the permanent hardness. In presence of acid, temporary hardness cannot exist.

There are other scale-forming constituents which may occur, but they are quite the exception, and should be treated by a modification of the process.

*Theory of Removal.*—Having now briefly considered the chief scale-forming constituents present in ordinary waters, we can outline a general theory for their removal. In the first place, the only rational method to employ, where the size of the installation

warrants it, is to effect that removal before the water enters the boiler, and not to depend upon any so-called boiler-fluid to be used in the boiler itself. Many hundreds of these nostrums are on the market, and their effect, like their nomenclature, is varied. To a certain extent, they mitigate scale in some instances; in others, they are quite valueless; but not in one case in a thousand are they really effectual. As a general axiom, they are simply used by rule-of-thumb, and in most cases they are not at all compounded in particular reference to the water with which they are used. In their really effective instances they are so because they precipitate the scaling constituents in a pulverulent condition, and also contain some ingredient (generally organic) which prevents this precipitated matter from settling on the plates, but renders it more or less flocculent, so that it can be easily removed by the simple process of sludging the boiler. But in the case of a large installation, their disadvantages as to cost, uncertainty, etc., are so obvious that it is unnecessary to dwell upon them. Fifty years ago, sometimes a dead dog was thrown into a boiler; it slowly dissolved and gave up organic matter, which kept the constituents pulverulent.

But anterior preparation, if successfully carried out, ensures the boiler-feed being of such a nature as to give the very best results from a steam-generating point of view, even when only a very—at first sight—unpromising supply of water is obtainable. Against the first cost of plant required, and the expenses of its upkeep, we have an enormous fuel-economy, a saving of labour, and a great decrease of wear and tear.

*Treatment.*—In the first place, the characteristics of the supply in question must be accurately ascertained, and that the supply can be softened without any difficulty. In broad principle, all the types of water-softening plant are dependent upon the same chemical reactions, and it is only in the mechanical means adopted for their application that the difference comes in, while the chemicals used are simple and inexpensive. Broadly, the reactions are as follows:—(1) Carbonates dissolved in carbonic acid, treated with lime, yield double the quantity of insoluble carbonates. (2) A soluble lime salt treated with carbonate of soda, yields insoluble carbonate of lime and a soluble soda salt. (3) A soluble magnesium salt treated with caustic soda yields an insoluble magnesia

hydrate and a soluble soda salt. (4) Sometimes caustic soda, added to the original water, with the carbonic acid, forms soluble sodium carbonate, and frees the insoluble carbonates, and the carbonate of soda so formed is used for reaction (2). The water to be treated is allowed to flow into a tank, and is then mixed with the requisite amount of the necessary reagents, the scaling constituents are thus thrown out as insoluble compounds, and separated as such, the clear and softened effluent going to the boilers.

*Apparatus.*—The reagent solutions and the quantity necessary, having been determined, various methods of causing the action between them and the water to be treated are made use of. The most elementary of these is to run the water into a plain tank of known capacity (say 10,000 gallons), and then to add the reagent solutions, agitate, and allow to settle. This method, however, has many disadvantages. (1) It demands a great deal of attention; (2) it is necessarily intermittent, the tank during settling giving no effluent; and (3) there is the comparative length of time which is necessary for the clarification of the water contained in a tank of considerable depth.

Let us for a moment notice the behaviour of a turbid solution contained for convenience in a transparent vessel. When deposition commences, the first sign of clearing begins at the top, and this layer of clean water gradually extends downward. The layer of water underneath has been rendered thick by the passage of this deposit downward; if this were not so it too would have become clear, by reason of the settlement of the suspended matter originally contained in it. This settlement has actually taken place, but the layer has not become clear because of the passage into it of the suspended matter from the layer above. If we, therefore, were to divide the tank into 10 layers by means of diaphragms, we should expect the settlement to be at least 10 times as rapid; and this is actually found to be the case. In some forms of apparatus, this fact is made use of, and the water treated is thus practically cleared as it is softened, a constant stream of the dirty water being admitted at the inlet and a suitably regulated constant flow of the reagent solutions introduced at the same time. This may be done automatically, especially if the water be pumped, by connecting small reagent pumps (with an arrangement for regulating the length of their

stroke) direct to the main water-pump, so that each stroke of the feed-pump causes a proportionate quantity of the reagents to be delivered.

Other methods advocate the passing of the water through a tower containing plates, arranged on the same principle, and secure a proportionate admixture of the precipitants by causing the dirty water to flow over a water-wheel into the mixing-vessel; this wheel works a bucket-elevator, whose buckets pick up the reagents as required. But this latter seems to be a somewhat cumbersome method of attaining the desired end, and chain-elevators are liable to go wrong, especially when working through liquids.

In addition, a store-tank has been proposed for the clarified softened water, containing a ball-valve, which automatically controls the inlet of the water, shutting it off altogether when this tank is full, and throwing the whole apparatus out of work, and opening the flow and simultaneously starting work when the water-level drops.

The reactions are brought about much more quickly and completely when the water is warm (at a temperature approaching 160° Fahr. preferably). Failing this, agitation helps to bring about the desired result. And this is the rock upon which most softening processes split. Some systems agitate by injecting air —a fatal mistake, as the less dissolved oxygen that a boiler-water contains the better it is for the boilers. Scaling may certainly be decreased, in fact, practically done away with, but if pitting or corrosion be fostered instead, it is a moot point whether the process has advanced the condition of the feed-water much, if any. The writer would have the boiler scaled rather than corroded.

And this is where treating water for boilers differs so vastly from treatment for domestic and individual use. It is an old saying that the dissolved oxygen-content of a water is proportional to its organic purity. This is certainly not true, for pure (from an organic point of view) deep well-waters may not contain anything like the amount of dissolved oxygen that a surface or river-water does, which is much more organically impure. But a steam-boiler is not like the human body, at least, in its physiological requirements. For the boiler, a measure of organic impurity—provided it be not of an acid nature (in which case it would be easily and cheaply corrected by a little soda, and this is of very rare occurrence)—does more good than harm from a boiler-work-

ing point of view; in fact, it is going back to the point that the writer emphasized just now; while the bad effect of dissolved oxygen (in pitting and corrosion) is directly proportional to its quantitative content.

Therefore any method of mixing, dependent on the injection of air, is inadmissible, and for the same reason the writer does not approve of the water entering the apparatus over a water-wheel, as this tends to aeration of the water. This aeration is the very thing which we want to avoid in boilers.

Paddle-mixing, however applied, is much to be preferred, but it is open to the objection that a large amount of power is required, as the resistance to be overcome is great, and furthermore, unless the paddles work at a very considerable speed the efficiency of the mixing, and consequently the speed at which the reactions take place, leaves much to be desired.

A system of centrifugal mixing is certainly desirable, for by its employment the power required is reduced to a minimum, no tendency to oxygenation is offered, and the efficiency of the mixing, and rapidity of the precipitation is brought to a maximum. For some years, the writer has been experimenting with centrifugal mixing, with very encouraging results, and he is now conducting some investigations with regard to its special adaptation to water-treatment.

*Filters.*—Having softened the water—and the chemical requirements of each individual installation would determine the nature and proportion of the reagents used—the next point is to separate all traces of suspended matter from it. This may have been already done by the subsidence-filter (diaphragms) previously mentioned, or by some modification of this device, at any rate, to a large extent. In some cases, where the plant is well above its work, or where a plant has been called upon to treat very much less than the quantity it was installed for, the effluent will be so clear as to need no further treatment, even when means for such treatment are provided. In most cases, however, some method of filtration for separating the treated water from the last traces of suspended matter is necessary.

An ordinary sand-bed filter is open to serious objections. It promotes oxygenation of the water, takes up a large amount of space (a serious consideration in many cases), is troublesome,

costly in upkeep, and difficult to clean without impairing its qualities. Its cleaning, of course, consists of paring off the top layer of sand and precipitate, and the replacement of fresh sand to form the top layer. The disadvantages of this form of filter are well known to all water-engineers, while its advantages from the point of view of hygienic supply only become further disadvantages from a boiler point of view; so that it is a form of filter which does not merit further consideration for this purpose.

An open cloth-filter is sometimes used, and has the merit of simplicity in principle, though this is discounted by the extra amount of trouble involved in cleaning. It consists of an ordinary open tank, into which the water to be cleared flows. In this tank is suspended a hollow disc, mounted upon a hollow spindle, which latter forms the outlet for the filtered water. On the sides of the disc are affixed perforated tubes (sometimes made of sheet-copper) and these tubes are wrapped with filter-cloths. The water flows through the filter-cloths (on which the suspended matter is left) and the united amounts passing through all the perforated tubes flow out through the hollow spindle.

Other filters are made by different firms (under various names) which consist primarily of a layer of suitable filtering material (generally granular) lying upon a grating with an air-space underneath, this grating being held in a wrought or cast-iron tank. These filters are sometimes covered, so that they can work under pressure. They are so made that they may be cleaned *in situ* without removal of the filtering-material, and it is in regard to the means of effecting this cleaning that the different makers chiefly vary. In some, by reversing the current of the water for a few minutes, the solid matter accumulated on the filtering medium is washed away down the drain, an effluent-cock being provided for this purpose. This method of cleaning is at the best unsatisfactory, as the benefit obtained is but temporary, and the whole of the filtering material has after a while to be removed from the apparatus and hand-washed, the slime not being all removed by simply reversing the current of water.

A decidedly better way of cleaning such a filter is to reverse the water and, at the same time, blow a current of compressed air through the filtering medium. This may be supplied from a hand or steam-blower attached to the side of the filter, or in some cases (*e.g.* a colliery where a compressed air-supply is handy) may

be simply connected up from the main. The whole medium and its contained impurities are thus violently agitated, and a much more efficient cleansing takes place, the separated dirt flowing away as before.

Where the quantity of suspended matter is small, a preferable type of filter to any other in the writer's opinion is the double cartridge telescopic one. The filter works under pressure only, and is connected immediately to the delivery of the feed-pump or injector. The water is forced into an egg-shaped receptacle, with one flat end, in which is contained a movable cartridge, wrapped with filter-cloth, and made of two phosphor-bronze or gun-metal gratings, one inside the other, the space between the two being packed with cocoa-fibre. All suspended matter is removed upon the surface of the cloth, and any oil or grease contained in the water, not removed by the previous process, is removed by its passage through the fibre. It is astonishing what the fibre will take up. The clarified water passes away from the hollow inside of the cartridge to the outlet of the filter. By a simple arrangement of three valves the filter can be by-passed. The cover at the flat-end is then removed, the cartridge drawn, and a spare duplicate inserted. By having the cover fastened with swing-bolts, this operation can be performed easily in 2 minutes. By having a blow-back connection, and also simultaneously causing a portion of the water pumped to flow backwards when the filter is by-passed, the cartridge can be cleaned *in situ*, the collected suspended matter being washed away, as before described, and a cartridge very seldom need be changed at all. In fact, if you have a good boiler-feed it would go 7 weeks without change. A pressure-gauge attached to the apparatus shows at once when the cartridge has accumulated much matter. The cocoa-fibre will last for many months without replacing, unless the quantity of dissolved oil is extraordinarily large.

Before leaving the clarification of softened water it will be interesting to note the way in which one system proposes to, and, in fact, does deal with the matter. As we have said before, the suspended matter, which causes the water to be turbid after softening, is generally calcium carbonate. This body, as we have seen, is insoluble (practically) in water, but soluble in carbonic acid. Therefore, they blow in carbonic acid and dissolve this calcium carbonate, thus, of course, clearing the water, but at the same time

re-hardening it to the extent of the amount of suspended calcium carbonate. Thus, they have performed work by one process to partially undo it by the next; a proceeding which hardly appears economical, to say the least of it. The carbonic acid is generated by drawing air through a coke fire and blowing it (in great excess) through the water. Besides the possibility of further introducing oxygen, and the great disadvantage attending the use of a water containing dissolved carbonic acid, ordinary coke always contains sulphur, generally to the extent of 1 or 2 per cent. When burned it forms sulphurous acid gas, which dissolves readily in the water forming sulphurous acid, this neutralizes the calcic carbonate, and forms calcic sulphite, which speedily oxidizes to calcic sulphate. Thus both temporary and permanent hardness are re-formed by this method of treatment, which, compared to filtration, has not, in the writer's mind, one single advantage to offer.

*Conclusion.*—The advantages of a properly purified feed-water need no insistence. A judicious selection from the foregoing methods will enable one to treat a water under absolutely the best conditions.

But if the treatment be not properly carried out, a state of things may ensue that is almost as bad as that arising from the use of the untreated original water. If too much lime be added, a hard, firmly-adhering, polished scale will be quickly formed. If caustic soda has been used, and used in excessive quantity, the water boils explosively and "kicks," the fittings are rapidly attacked, and the boiler readily primes. The copper dissolved from the fittings in its turn acts chemically on the iron and is precipitated, with the simultaneous passage into solution of an equivalent quantity of iron, thereby giving rise to wasting and pitting of the plates. Sodium carbonate in excess also acts prejudicially, though not to the same extent as caustic soda. It does not so much tend to the formation of pitting.

The writer is of opinion that the very best way of dealing with a water is the addition automatically of the requisite chemicals to take up the dissolved carbonic acid, and to precipitate the carbonates and other scaling constituents; the introduction into that water of all the exhaust-steam available to warm it as much as possible; the violent and prolonged agitation of that water and the reagents by centrifugal means, whereby the maximum effect is

obtained with the minimum power: that is the most important point of all; the simultaneous admixture of a chemical which will cause the precipitated matters to settle quickly and promote at the same time the removal of as much of the oily matter as possible; the use of a series of diaphragms and subsidence-plates, so arranged as to give a practically clear effluent; and the employment of a filter of the telescopic cartridge type (slightly modified from existing patterns, and having a back-wash cleansing arrangement, together with air-injection) on the delivery of the feed-pump.

Such a combination the writer hopes to have the pleasure of placing before the members in descriptive detail at no distant date, provided that the subject is of sufficient general interest.

Meanwhile the writer has endeavoured, with but a poor measure of success, to bring concisely to your notice the chief constituents of a water which cause scaling, and the way in which they do so, together with the principles and the broad lines of the practice brought into play in their removal; and he will be only too pleased to answer any questions that may be asked, the answers to which may serve to make his previously attempted explanations more clear.

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The PRESIDENT (Mr. W. N. Atkinson) said that the subject of feed-water for boilers was one of interest to colliery-managers, because the water available at many collieries was not suitable for boiler purposes; and it was a subject the importance of which was likely to increase, owing to high pressures of steam coming into use and the more complicated construction of boilers. It was not a subject upon which he had had any practical experience, but he had often seen the results of the use of bad water for boilers in the shape of heavy scaling and corrosion. He thought that the subject was worthy of more consideration that it usually received from boiler-users, when they remembered the injury frequently done to boilers, loss of fuel, and increased cost of cleaning the boilers. The use of an efficient softener and purifier would in many cases be an economical measure.

Mr. B. WOODWORTH said that it used to be a common practice to throw in a quantity of potatoes when a boiler wanted cleaning. Some years ago an engineer made a decent fortune by a system of heating water with live steam, and it removed many of the impurities before they got into the boiler.

Mr. E. B. Wain said that Mr. Smith had dealt with the matter from a chemist's point of view, and there was one point which could not be emphasized too strongly; that impure matter should be removed, if possible, before it got into the boiler. Boiler-fluids used for softening scales in a boiler seemed fallacious nostrums; as the scale was still there; it was deposited in the boiler, and although not in a hard form, it was in such a condition as to constitute a non-conductor. If they could remove suspended mineral matters from the feed-water, they were enabled to save the hard scaling and much trouble in the boiler. Sometimes this removal had been done in filter-beds with good results.

Mr. John Heath said that he had known enginemen who used dead dogs or dead cats, or even a sheep. In a range of egg-ended boilers he found some to be continually scaling at 60 pounds pressure. They used ½ gallon of crude oil, and that made the boilers as clean as when they came from the manufacturers. The insurance companies did not like them to use oil, but the difference lay between vegetable and mineral oil. He had used mineral oil, which made the boilers clean, and they had not scaled since.

The President (Mr. W. N. Atkinson) asked if paraffin oil was still being used?

Mr. Heath replied that after the boilers became clean, the oil was not used.

Mr. E. B. Wain remarked that there was a process used largely a year or two ago, of loosening the scale or keeping it down by the admission of petroleum by means of a small injector.

The President observed that the object of that method would be to form a coat on the plates which would prevent the scale from adhering.

Mr. B. Woodworth said that he had known petroleum to be used, but he did not know whether it had a permanent effect.

Mr. A. Hassam said that he had used water from the Ten-feet coal-seam, and it did not seem to do any harm at a boiler-pressure of 100 pounds, but the water from the Seven-feet Banbury seam was very destructive to the boilers.

Mr. E. B. Wain said that the water from the Seven-feet Banbury seam was the best that he had at his colliery.

Mr. A. HASSAM said that the Banbury mine-water was deleterious, owing to the acids contained in it causing excessive corrosion.

Mr. J. K. SMITH observed that every day the steam-pressure was getting higher, and the question of good water became more and more important. With high-pressure steam good feed-water was of the highest importance. The body of a dead dog or sheep, or a sack of potatoes had the same action in a boiler. Dissolved organic matter kept the scale more pulverulent, and therefore in technical language the scale was freer, and it did not matter whether they used a donkey or potatoes. The manager of some French works had a very troublesome scale, and he got over it by the use of pure mineral oil. It simply softened the scale and rendered it easier to part. But in most cases mineral oil would do more harm than good.

The PRESIDENT moved a vote of thanks to Mr. Smith for his valuable paper.

Mr. E. B. WAIN seconded the motion, which was adopted.

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## DISCUSSION OF MR. D. BURNS' PAPER ON THE "WEIGHT OF WINDING-DRUMS FOR DEEP SHAFTS."*

Mr. J. T. STOBBS said that he had read Mr. Burns' paper with considerable interest, as it drew attention to one of the mining questions of the future, that is, the advisability or otherwise of using large drums for deep winding. He was surprised to read that "should the quantity of motion or momentum thus communicated to the drum be utilized in doing its useful work at the end of the run, and after the steam has been shut off from the engine, there is no loss, if we neglect that due to friction."† But surely the loss of time was the greatest of all the losses in deep winding. It was unfortunate that the writer had not confined his remarks to practical considerations, rather than to the mechanics of the question; because the mechanics adopted were totally inadequate for the purpose, and to that extent the paper

* *Trans. Inst. M.E.*, vol. xx., pages 49 and 154 ; and vol. xxi., page 53.

† *Ibid.*, vol. xx., page 49.

was actually misleading. The mechanics necessary for the solution of this question were those of the rotation of a rigid body, and not the translation of a heavy body, because the centre of gravity of the drum is not lifted by its rotation, consequently the writer's treatment of the problem was fundamentally erroneous. In the paper,* an old text-book nostrum that "friction is proportionate to the pressure between the surfaces in contact," is introduced, regardless of the limits within which the experiments, upon which this law was based, were actually made. Prof. Thurston, experimenting on machinery approximating in action and weights to the drums in question, found that friction varied inversely as the square root of the pressure between the surfaces in contact: a very different law. The great point in the design of winding-drums had been altogether omitted, and that was the distribution of weight; and, consistent with strength of structure, the heavy parts should be so arranged that the moment of inertia of the drum was a minimum. The illustrations and particulars would have been more in harmony with the title of the paper, if the weights of the drums had been given, but this information had been withheld. Whilst the winding-drum shown in Fig. 2 seemed lighter than that shown in Fig. 1, it was certain to produce more churning of the air, and to that extent would be more wasteful of energy.

Mr. B. WOODWORTH said that Mr. Burns was right as to his general principles, as the heavier the drum the greater would be the amount of power required to produce the momentum required and if the time could be spared for it to be utilized in finishing the winding, no loss would occur beyond the amount of the friction; but, as Mr. Stobbs said, that was practically out of the question, if they were to do the work for deep mining. Consequently, the momentum had to be checked by the use of the brake or compression in the cylinders to ensure quick stopping, and very great waste of power took place. The first case of which he took particular notice was that of an engine with a comparatively light drum, and from a rough calculation he found that it took the full power of the engine for over three revolutions to get up the momentum of the moving parts, so that when a heavy drum was used of whatever class, spiral or otherwise, it became a serious factor of loss.

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* *Trans. Inst. M.E.*, vol. xx., page 52.

# SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD AT THE BIRMINGHAM UNIVERSITY, JUNE 3RD, 1901.

MR. W. J. HAYWARD, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

Mr. W. W. E. SHAW's paper on "Colliery Book-keeping and Accounts" was read as follows:—

## COLLIERY BOOK-KEEPING AND ACCOUNTS.

BY W. W. E. SHAW.

As coal is the principal item at a colliery, it will be desirable to consider the books and statements relating to the output. The first one to commence with is the "pit-drawings book," which should contain a daily record of all the drawings, and from this a return should be made each morning to the manager, of the previous day's output. A card, ruled as shewn in Form A, if

FORM A.—KENT COLLIERY. DAILY OUTPUT.

| DAY. | | | | | |
|---|---|---|---|---|---|
| Friday<br>Saturday.<br>Monday.<br>Tuesday.<br>Wednesday<br>Thursday. | | | | | |
| Totals | | | | | |

printed also on the reverse side, will show the daily drawings for 10 weeks, thus enabling a comparison to be made between several days or weeks. The manager should also receive a weekly return of the drawing, etc. This form should contain the fullest information as to the output, together with the length of gate-roads

driven during the week, and any other information thought necessary. Form B is an example of such a return, but a suitable one can be easily designed to suit special requirements.

FORM B.—KENT COLLIERY. WEEK ENDING.................................1901.

| DATE. | | COAL RAISED. | | | | | | | | TOTAL NO. OF TUBS. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Time Worked. | | | Coal. | Slack. | Total. | Dirt. | | Dirt. | Drawn Coal and Slack. | |
| | F.<br>S.<br>M.<br>T.<br>W.<br>Th. | C.* | F.† | W.‡ | Tons. Cwts. | Tons. Cwts. | Tons. Cwts. | Tons. | | | | |

| ANALYSIS. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| REMARKS. | Senders. | Quantity. | Per-centage | Coal. | Per-centage | Slack. | Per-centage | |
| | Stallmen—<br>Coal<br>Slack | Tons. Cwts. | | Tons. Cwts. | | Tons. Cwts. | | |
| | Company—<br>Coal<br>Slack | | | | | | | |
| | Total<br>Dirt | | | | | | | |
| | Total<br>Engine | | | | | | | |

YARDAGE.

........Stall-heading. .... ..... Gate-roading. ...........Total Yards.

GENERAL REMARKS

* Time commenced. † Time finished ‡ Hours worked.

Another matter closely connected with the output is the making-up and payment of wages. This is a very important matter, and unless very carefully safe-guarded offers an easy method of defalcation, it is very necessary, therefore, that the making-up and payment of wages, should be worked upon a good system. The greatest safety lies in having as many persons as possible concerned in the carrying out of this: a further precaution being never to leave the payment of wages in charge of the person responsible for the checking of the wages-book. After having seen many systems, as good and safe a one as the writer has yet met with, is one where the time as worked, with the rate of pay, is entered into the wages-book by a respresentative from the manager's office, assisted by the different time-keepers. Clerks then work out the amounts due, and make the several deductions in the shape of rents, coal-draw-

ing, candles, powder, etc. A third person, not connected with the general office, then checks the calculations and additions; and before parting with the book writes the total amount of the same in words. This precaution will prevent any tampering with the book between the periods of checking it and the drawing of the wages-cheque. Payments are then made by a fourth person, who has had nothing whatever to do with the making-up or checking of the wages-book. The workmen are each supplied with a metal check, on which is their number; this they keep constantly in their possession, and on pay-day show it to their timekeeper, who then gives them their pay-check, bearing a similar number. On arrival at the pay-office, they leave their pay-check, receiving in exchange their wages, which have previously been put up ready for them in numbered trays. The writer should have mentioned previously that the manager examines the wages-book regularly as to rates, etc., and on satisfying himself that the same are correct signs the book.

FORM C.—KENT COLLIERY. OUTPUT AND ITS DISPOSAL FOR WEEK ENDING ........................................ 1901.

| Date. | Output. | Distributed to | | | |
|---|---|---|---|---|---|
| | | Canal. | Railway. | Landsale Wharf. | Boilers. |
| | Tons. Cwts. | Tons. Cwts. | Tons. Cwts. | Tons. Cwts. | Tons. Cwts. |
| | | | | | |

| How Disposed of. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Canal. | | Railway. | | Landsale Wharf. | | | Total. |
| Sales. | Overweight. | Sales. | Overweight. | Sales. | Allowance Coal. | Offices, &c. | |
| Tons. Cwts. | Tons. Cwts. | Tons. Cwts. | Tons. Cwts. | Tons. Cwts. | Tons. Cwts. | Tons. Cwts. | Tons. Cwts. |
| | | | | | | | |

Some scheme should be adopted at every colliery by which the total output can not only be traced to the different departments, but also accounted for by them. This is the only check on the departmental managers, as if one of them were in collusion with any of the customers, greater overweight than was stipulated might be given, or even large quantities of coal gradually taken away from the colliery without its loss being discovered. Of

course, if it were desired actually to balance the output each day it would be necessary to take stock daily, but it would probably be found sufficient if an actual balance was made at the end of the week. The advantage obtained by having the sheet written up daily being that, in the event of a discrepancy appearing at the end of the week, the tracing of it would be simplified by examining the details of each day's transactions. Whether it would be necessary to divide the coal and slack would depend upon circumstances. To do so would complicate the sheet, as probably some of the output returned as coal would be sold as slack, and this would have to be taken into account. Form C is intended for use at a colliery where it is not considered necessary to make this division. At the end of the week, add the sheet straight across and if the weights of coal distributed among the departments be added together, the addition should give the output; if not, some of the coal raised has never been sent to the departments, provided that no error has been made in the weights. To the different weights of coal sent to the different departments, add to each, the stock brought forward from the previous week, then add together the several figures obtained from such additions and the total tonnage, for which the other side of the sheet has to account, is obtained. Now for the other side, after the addition of the several columns has been made, add to the sales column of each department the present stock, and carry these items into the total column. If the total column addition, as representing the tons disposed of during the week plus the stock yet in hand, accounts, or substantially does so, for the tonnage mentioned previously when speaking of the other side of the sheet, namely:—the total weight of the coal sent to the different wharves plus the stock brought from the previous week, then the result may be considered satisfactory; but if not, then an investigation is necessary in order to ascertain in which department the deficiency occurs. This can be easily brought about by adding together sales, overweight and stock in the case of the canal and railway sales; sales, allowance-coal, office-consumption and stock in the case of the land sales: the total of each of these separate additions should then agree with the total obtained by adding together the coal sent to the department plus the stock brought from the previous week. From the manager of the department in whose column a discrepancy occurs, an explanation should be demanded as to what has become of the coal sent to him.

A daily return should be made from each department of its sales, whether a sheet as mentioned above be kept or not. When speaking of sales, the writer means coal-sales only, such items as tonnage, freight, cartage, wagon-hire and boat-hire charged to customers being kept in accounts entirely distinct from the coal-sales, and these accounts are debited with the charges incurred in respect of these matters. There are two advantages obtained from dealing with the figures in this way, one being that the average selling price calculated at the end of the year represents coal only, the other being that the profits or losses on tonnage, freight, etc., are shown monthly as the totals are posted, thus enabling any insufficient charges to be remedied before the loss has become excessive. If this system be not adopted the colliery may easily lose money without being aware of it, either through not making sufficient provision for the charges to be made against the colliery in respect of these items, when quoting; or, in the case of wagon-hire, by customers' detention of the wagons, caused by the neglect of the clerk responsible for looking after the traffic. Even if a colliery possesses its own wagons or boats, the same remark applies, the only difference being that then the only charges made against the wagon-hire or boat-hire account will be for repairs, or some similar item directly affecting the wagons or boats. Just the same with cartage, it is of great importance that this should be done when an outsider contracts for the carting, and it is better to do so where the colliery does its own; in the latter case, the cartage-account should be charged with the wages of the men employed in delivering coal, and with a reasonable amount for the hire of the horses so employed, this charge for horse-hire being placed against the cost of their keep. Of course, only the time of men and horses employed in delivering coal sold to customers must be charged against this account. In the cases of tonnage and freight, the balance of the accounts will be the difference between the amounts charged to customers and those paid to the railway and canal companies.

It may be desirable to mention here the cartage of allowance-coal. An account for this should be opened, and credited with the amounts received from the workmen for drawing. The account should be debited with the wages of the men employed in delivering the allowance-coal, and with a sum for the hire of the horses so employed. If the balance of this account is on the

wrong side, then either not enough is being charged to the workmen for the drawing, or the men so employed are making too few journeys per day.

A requisition-book should be kept of all stores required, and signed by the managing director, works committee, or some responsible person, before the stores are ordered. On the receipt of the goods, they should be duly recorded by the person authorized to receive them; so that it shall be actually known that the stores are on the ground before payment of the account. In the case of small stores, which are used in exactly the same condition as that in which they are received, and of which, being easily carried about, pilfering could readily take place; the storekeeper should not be allowed to distribute any of them, without an order being presented to him, signed by the manager or his representative, and he should in addition be compelled to keep a record of those stores that he delivers just as he does of those that he receives. His book can then be compared, as to the latter, with the invoices, and as to the former with the manager's orders for distribution: the balance of his book representing the undelivered stores; if he has not these in stock when required to balance his book, some explanation is needed. The invoices can then be compared with the goods-received book as to quantity, and should be signed as to price by some responsible person, unless the requisition-book records the price at which the stores are to be purchased, and then the invoice should be compared with that book. The account can then be checked with the invoices, and is ready for payment.

It is usual, during the year, to present some statement of costs, and weekly and monthly sheets are the ordinary methods by which this is done. Form D is suggested as an example of the former, and explains itself. Stock-sheets, the collective results of which cannot be reconciled with the profit or loss of the annual trading account, are worse than useless as they are often misleading. Great care should therefore be exercised in calculating the figures to be debited against the week under the heading of "cost of production," in order that they may cover every charge which it is possible to foresee can be made against the colliery during the year in question. If one has the advantage of being able to look through the annual trading accounts of several previous years, the debits for such items as stores, depreciation, etc., can be generally arranged satisfactorily by a charge of so much per ton on the sales.

Rates, taxes, salaries, and interest should be actually taken out and divided by 52 weeks, as the exact amount chargeable against the year will be known. If relying upon past years' figures only, and it is known at the time that some of these charges will be increased during the current year, a sum should be added to the average, as shown by previous years' accounts, so that adequate provision may be made to cover every contingency. It is much better to be on the safe side, and to estimate these figures at too

TABLE D.—KENT COLLIERY. STATEMENT OF PRODUCTION, SALES, ETC., FOR WEEK ENDING,............................................................ 1901.

| PRODUCTION. | Statute Weight. | Percentage. |
|---|---|---|
| Quantity raised— | T. C. | |
| Coal .. .. | | |
| Slack .. . | | |
| Total .. | | 100·00 |
| Distributed as under— | | |
| Works consumption | | |
| Workmen's coal | | |
| Allowances .. | | |
| Coal Saleable .. | | |
| | | 100·00 |
| Days worked............... | | |

| SALES AND STOCK. | Canal. | Rail. | Land. | Totals. | Value. | Percentage |
|---|---|---|---|---|---|---|
| | T. C. | T. C. | T. C. | T. C. | £ s. d. | |
| Best Coal .. | | | | | | |
| Seconds Coal . | | | | | | |
| Forge .. . | | | | | | |
| Rough Slack .. | | | | | | |
| Engine Slack | | | | | | |
| Average Cost. | | | | | | 100·00 |
| | | | | | | Average price per Tn s. d. |
| | Coal | Slack | | | | |
| | | | | | | Present Stk |
| | | | | | | Stock last week. |

| COST OF PRODUCTION. | £ s. d | Per Ton Sold. s. d. | Per Ton Raised. s. d |
|---|---|---|---|
| Pit Wages .. .. .. | | | |
| Surface Wages.. .. .. | | | |
| Stores .. .. .. .. | | | |
| Depreciation of Fixed Plant and Estate .. . | | | |
| Depreciation of Loose Plant | | | |
| Rates and Taxes .. .. | | | |
| Interest and Bank Charges.. | | | |
| Office Wages .. .. .. | | | |
| Salaries & Directors' Fees.. | | | |
| General Charges .. .. | | | |
| Total .. .. | | | |

| | |
|---|---|
| Saleable Coal .. | |
| Less Cost of Production . | |
| Estimated Colliery* .. | |
| Add Estimated Income from Estate . . .. | |
| Estimated* for Week .. | |

| |
|---|
| REMARKS— |

* Insert "Profit" or "Loss" as the case may be.

high, rather than at too low an amount; for, be as careful as one will, there is always some item unexpectedly cropping up which has not been provided for. One advantage in making a fixed charge, based upon the tons sold, for the items likely to vary much, rather than in endeavouring to use the actual figures, is that the burden falls heaviest upon those weeks best able to bear it; and in addition, by so doing, the charges are more equally distributed

over the whole year, instead of falling heavily upon one period whilst another escapes in comparison lightly. Take the case of ropes, if these were all charged against the sheet for the week in which they were received, the result would of necessity be a heavy loss, while the rest of the year would probably show a big profit, gained at the expense of the one week which bore the charge.

FORM E.—KENT COLLIERY. STATEMENT OF COST OF PRODUCTION, SALES, ETC., FOR ............ WEEKS, ENDING ............ 1901.

DR.

| | | Statute Tons. | Percentage. | Average Cost Per Ton. |
|---|---|---|---|---|
| Total Quantity of Coal raised .. .. .. .. | Tons. Cwts. | | | |
| Works Consumption .. .. | | | | |
| Workmen .. .. .. .. | | | | |
| Allowance and Deficiency .. | | | | |
| Saleable Coals .. .. .. .. .. | | | | |
| | | £. s. d. | £ s. d. | s. d |
| WAGES:— | | | | |
| Stallmen .. .. | Coal-getting .. .. .. .. .. | | | |
| Stall-heading .. | .. .. .. .. .. .. | | | |
| Deputies .. .. | .. .. .. .. .. .. | | | |
| Repairers .. .. | .. .. .. .. .. .. | | | |
| Haulage .. .. | .. .. .. .. .. .. | | | |
| Horse-Drivers and Keepers .. .. | .. .. .. .. .. .. | | | |
| Door-tenters .. | Door-boys and Lamp-cleaners .. | | | |
| Cagers .. .. | .. .. .. .. .. .. | | | |
| Gate-roading—Exhausted .. | Estimated at per ton .. | | | |
| Ditto .. .. | Extra cost of driving over per yard .. .. .. .. .. | | | |
| Banksmen .. | .. .. .. .. .. .. | | | |
| Haulage on Surface .. .. | Engine-tenter and Nipperers .. | | | |
| Boat, Truck and Cart-loading .. | .. .. .. .. .. .. | | | |
| Team-work .. | Balance, after deducting amount received for Coal-drawing .. | | | |
| Joiners, Smiths, etc. .. .. | Joiners, Smiths, Bricklayers and Fitters .. .. .. .. | | | |
| Engine Working, etc. .. .. | Engine-tenters, Firemen, Ash-wheelers and Cleaners .. .. | | | |
| General Labourage | Labourers, Watchmen, Store-keeper, Oilers and Chaff-cutters | | | |
| Clerkage .. .. | Office, Machine and Canal-wharf Clerks .. .. .. | | | |
| STORES & MATERIALS:— | | | | |
| General Stores .. | .. .. .. .. .. .. | | | |
| Oil and Grease .. | .. .. .. .. .. .. | | | |
| Timber .. .. | .. .. .. .. .. .. | | | |
| Iron and Castings | .. .. .. .. .. .. | | | |
| Horses' Keep .. | No. of Horses Average per week each .. .. | | | |
| Candles .. .. | .. .. .. .. .. .. | | | |
| Ropes .. .. | .. .. .. .. .. .. | | | |
| Loose Plant .. | Depreciated at the rate of per annum .. .. .. | | | |
| INCIDENTAL CHARGES, Estimated .. | Depreciated at the rate of per annum .. .. .. | | | |
| ESTATE and PLANT, Depreciation . | Estimated at per sale ton .. .. .. .. .. | | | |
| GENERAL CHARGES:— | | | | |
| Management and Directors' Fees | .. .. .. .. .. .. | | | |
| Rates and Taxes | .. .. .. .. .. .. | | | |
| Interest .. .. | Proportion of Balance, after deducting Rents .. .. | | | |
| Truck-hire .. .. | Balance after deducting Earnings | | | |
| Miscellaneous Expenses .. .. | .. .. .. .. .. .. | | | |
| | Farms .. .. .. .. | .. .. .. | | |
| | Balance—Profit for the Month | .. .. .. | | |
| CAPITAL OUTLAY:— | | | | |
| To Gate-roading .. | No. of yards driven at per yard .. .. .. .. | | | |

FORM E.—*Continued.* CR.

| | Sales and Stock. | Value. | Total. | Av'age Price. Per Ton. |
|---|---|---|---|---|
| SALES BY CANAL:— | Tons. Cwts. | £ s. d. | £ s. d. | s. d. |
| Best House Coal .. .. .. .. | | | | |
| One Way Coal .. .. .. .. .. | | | | |
| Lumps .. .. .. .. .. | | | | |
| Rough Slack .. .. .. .. .. | | | | |
| Engine Slack .. .. .. .. .. | | | | |
| SALES BY RAIL:— | | | | |
| Best House Coal .. .. .. .. .. | | | | |
| One Way Coal .. .. .. .. .. | | | | |
| Lumps .. .. .. .. .. | | | | |
| Rough Slack .. .. .. .. .. | | | | |
| Engine Slack .. .. .. .. .. | | | | |
| SALES BY CART:— | | | | |
| Best House Coal .. .. .. .. .. | | | | |
| One Way Coal .. .. .. .. | | | | |
| Rough Slack .. .. .. .. .. | | | | |
| Engine Slack .. .. .. .. .. | | | | |
| Total Sales .. .. | | | | |
| Add Stock on hand .. .. .. .. .. | | | | |
| Deduct Stock on hand .. .. .. .. | | | | |
| Abatements, Discounts and Allowance for Bad Debts .. | | | | |
| CAPITAL OUTLAY:— | | | | |
| By Gate-roading Exhausted—Amount debited to Trade Account | | | | |

Monthly sheets (Form E) may be prepared, so as to afford more information than the weekly ones. The wages-sheets should be analysed so as to show the cost of each class of labour, and the stores divided into their several divisions. The items for stores may be either taken from the invoices for the goods actually received during the four weeks covered by the wages included in the sheet, or the total purchases of the previous month may be taken as representing this charge. The latter plan will probably be found to work the best, seeing that the books will be made up monthly, and if this plan be adopted the totals for the month will be all ready to deal with, instead of one having to make calculations for broken periods. Provision must be made for excluding from the sheet the material still in stock; this is, of course, impracticable in the case of a weekly sheet, hence another reason for making the weekly charges by way of percentage. Costly expenditure such as ropes, etc., is better estimated, so as to equalize the charge throughout the year. For candles, powder and other stores sold to the workmen, a deduction from the purchases should be made. Depreciation of plant and exhaustion of estate should be provided for, and charges such as rates, taxes, directors' fees, salaries and others of a like nature carefully calculated. The profits or losses on wagon-hire, boat-hire, freight, tonnage and cartage should be included; then, with a full description of the sales, the stocks of coal at the beginning and end of

the month, and the income from the estate, the sheet should be complete, and the balance will show the profit or loss for the month.

As with the weekly sheets, so with the monthly ones, if they are to be of any value whatever they must give results that when taken collectively can be reconciled with the result as shown by the annual trading account. The greatest care therefore should be exercised in fixing those charges which are estimated, and if it be known that any capital expenditure is to be written off to revenue at the end of the year, a proportionate amount of this sum should be charged each month.

Of the annual trading account little need be said: if the books have been carefully and accurately kept, every purchase and sale will have been properly recorded, but care must be taken to include every liability, and if the exact amount of any one cannot be ascertained, then an estimate must be made for it, based upon the most reliable information that is to hand. Provision must be made for depreciation of plant, and, if the colliery is working its own mines, for the exhaustion of the estate, this latter item being probably fixed at a rate per ton upon the coal raised. All royalties should be included, and the stocks carefully taken and priced at cost, unless the material has either deteriorated in value or the present price of it has fallen below what it was at the time of purchase. If material has been purchased, and is already in use, but the expenditure in respect of it will carry the colliery on for several years without the necessity for fresh outlay of a similar character, it is permissible to extend the charge for such material over the term of years which it is estimated that it will last. It is well not to be over sanguine as to the length of time which this material is expected to wear, as it is much more pleasant to find yourself a little better off at some future time than you expected, rather than face to face with the necessity for another heavy outlay before the previous one has been completely written off.

There are very few items on the balance-sheet that need consideration, but two or three of them call for some mention, among them being the item "minimum rent in excess of royalty on coal worked." If it be known that some portion of this item will never be recouped out of future royalties, it should be written off at once, and if there is any doubt as to its being so recouped, then a royalty suspense-account should be opened and credited with a sum sufficient to cover the doubtful asset.

Another item deserving of mention is the capital value of wagons being acquired on purchase-lease. Of course in these transactions, the annual payments to the wagon company represent both purchase-money and wagon-hire. There are several ways of determining the amount to be charged to capital. One method, which possesses the advantage of simplicity and yet has been found to work as satisfactorily as any other, is to estimate how much each wagon will be worth at the end of the lease, that is to say, when it becomes the colliery's own property. Divide this sum by 5, 7 or whatever number of years the lease runs over, and charge this amount per wagon each year to an account for "the capital-value of wagons on purchase-lease," putting the remainder of the annual payment to wagon-hire. At the expiration of the lease, you will have standing in the "wagons on purchase-lease account," by means of the annual charges to capital, the value assigned to these wagons; then transfer this amount to wagon account, which account should represent the wagons belonging entirely to the colliery.

Gate-roading is another item peculiar to a colliery balance-sheet, and it is a rather dangerous asset in consequence of the possibility of some portion of it being swept away suddenly through an accident. This, therefore, is a reason for keeping it at as low a figure as possible, or for building up a reserve fund sufficient to meet any unexpected loss in respect of it. The value put down for the gate-roading should be the cost of driving the roads, over and above the value of the coal obtained in doing the work; and all gate-roading lost must be either charged against that year's trading account in which it has been lost, or transferred to the reserve fund, created out of profits, to meet such losses.

There are probably many shortcomings in this paper and very possibly many things with which the members will disagree. The writer does not lay down these statements as rules, which must be followed, but merely offers them as suggestions; and if he has presented the accounts more from an accountant's than from a colliery manager's point of view, force of habit must be his excuse.

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The Chairman moved a vote of thanks to Mr. Shaw for his interesting paper.

Mr. A. Sopwith seconded the resolution, which was agreed to.

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Mr. F. G. Meachem's paper on "Timbering in Mines" was read as follows:—

# TIMBERING IN MINES.

By F. G. MEACHEM.

Ever since a Royal Commission was appointed to enquire into accidents in mines, H.M. inspectors of mines in charge of the various districts have persistently worked for systematic timbering. Dr. C. Le Neve Foster, while visiting the Paris Exhibition, saw an exhibit illustrating the method of preventing falls of roofs, adopted at the Courrières collieries, France, and was so much impressed with it that he made a special report to the Home Office, which was issued by the Secretary of State, and copies were sent to the principal collieries.* From statistics, it would appear that the French are ahead in safety of all the collieries in the world as regards fatal accidents from falls. The following figures show the comparative death-rates from falls per 1,000 persons employed underground in different countries:—France, 0·58; Great Britain, 0·78; Prussia, 1·22; and Pennsylvania, U.S., 2·11. These figures show that there is ample room for improvement in this country.

Systematic timbering has been in force for some years at the Cannock and Rugeley collieries. The Courrières system consists of iron bars driven over the top of the settings of timber, and the coal in no case is under-gone. The comparison then stands thus: France, output 333 tons per man per annum; Great Britain, 441 tons per man per annum; and this gives our country a lead in coal-production of about 108 tons per man per year. If the Courrières system were adopted, there would be a reduced output in this country, as follows:—We would employ 583,009 men at 108 tons decreased output, equivalent to 63,000,000 tons reduction in output per annum. The cost for timber is said to be about 8½d. to 1s. per ton. The cost in Great Britain varies from 3½d. to 5d. per ton, so that it would entail an increased cost of about 5d. per ton on 200,000,000 tons, or a loss of about £4,166,663; and further, with the increased use of timber, its price would rise considerably.

* *Trans. Inst. M.E.*, 1900, vol. xx., page 164.

The system adopted at the Courrières collieries could not be worked, if the mines were as gaseous as those of our own district or South Wales. Coal-cutting machinery could not be used, and one of their special rules provides that if the seam exceeds an angle of 10 degrees, it must not be worked uphill.

As regards the value of the respective coals at the surface, the average for Great Britain is about 6s. 11d. per ton, while in France it is 9s. 1¾d. per ton.

These remarks are not made with the idea that we should not adopt the systematic timbering in some modified form, but the writer does most distinctly say that it is absurd to propose that the roof should be timbered whether it be as hard as iron or as soft as sand.

At the present moment there are serious outcries respecting the wane of British trade, that we are, or shall be, undersold by American coals; and that the Americans are using coal-cutting machinery in their collieries more extensively than we are at home. No doubt to a great measure the Americans will be able to compete with us, because they are not hampered by so many Government restrictions and local taxes as British mines, but when the death-rate per 1,000 workmen employed is compared, it is 3 in America to our 1.

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Mr. W. J. Hayward did not think that the Courrières methods of timbering would be practicable in South Staffordshire.

Mr. A. Sopwith and Mr. R. S. Williamson briefly endorsed this opinion.

Mr. Alexander Smith stated that the Mining Association of Great Britain had ascertained the feeling of the mining districts (including South Staffordshire) upon the suggestions made by the Home Secretary as to timbering in mines; and, generally, opinion was favourable to them, so far as local conditions allowed of their application. The Home Secretary had also expressed his satisfaction as to the manner in which mine-owners and mining-engineers had received his suggestions.

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# THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON,
MAY 23RD, 1901.

MR. H. C. PEAKE, PAST-PRESIDENT, IN THE CHAIR.

The CHAIRMAN delivered the following address:—

## ADDRESS.

BY H. C. PEAKE.

I am sorry to announce that Sir William Thomas Lewis, our President, is unable to be present and give us the benefit of his great experience, and the more so, as it falls to my lot,—that is, on your account—to have again to preside at this, your London meeting.

The ordinary address cannot be delivered at this meeting, owing to our President's absence, but there are one or two subjects very prominently before mining-engineers at the present time, on which I may be permitted to make a few remarks. One is the matter of timbering, which has been forced upon us by the Home Secretary. In the Staffordshire district, in which I am interested, systematic timbering has been in operation with most satisfactory results for nearly thirty years. One colliery, at which the system was first adopted, only had a death-rate of 0·14 *per annum* per 1,000 men employed, from falls of roof, over an average of years, or less than those which had taken place at the Courrières collieries, in Franee, to which attention had been drawn by the Home Secretary. Considerable opposition was at first made to the suggestion that there should be systematic timbering, but now that it is more fully understood, I am of opinion that it will be found advantageous to all districts to carry out the plan, which will, to my mind, be conducive to greater safety, without eventually adding to existing expenditure.

While on this subject I would refer to Prof. Louis' experiments on the difference between wet and dry timber, and from following the conclusions at which he had arrived, namely, that dry timber was so much stronger, in a rough way, it would appear that the timber costs are considerably reduced and that with a greater factor of safety.

Another question—although not a strictly mining engineering one—that of the tax on coal exported, is causing great excitement among those interested, but chiefly among those who are exporting coal. From what I believe is generally understood, many countries give bounties to enable their inhabitants to export goods; but this tax is the reverse, in fact it will act as a bounty on coal exported from other countries, and the effect of it must be that in place of sending coal to pay for our imports, we shall be obliged, to a certain extent, to send gold, that is, if we cannot send other commodities. An export-duty of 1s. per ton on best South Wales coal, as the price was on the small surplus for disposal over contracts last year, is a small matter, but what will be the effect on small coal when the average price of all coal is under 6s. per ton?

No one, who has spoken in the debates on the subject, seems to have sufficiently realized that there are bad and good times, and that one is the natural sequence of the other; but the whole argument is now based on the recent good times. What the effect of the duty will be is, at the moment, very uncertain, but it is probable that after a short time, it may not fall on the coal-owner. No one will invest money in a colliery until collieries, as a whole, are making a fair return over a series of years, and then, it must not be lost sight of that when sinking, the primary operation, is commenced, it takes several years to develop a colliery into full work. At the present time, notwithstanding the large profits supposed to have been made, they have not, so far, been sufficient to cause more than an average amount of capital to be put into the business—an amount not more than sufficient to make up for the natural exhaustion, and which leaves nothing for the ordinary increase in consumption. This being the case, I do not see, after the fluctuation in business caused by the impost of the tax is overcome, that coal-owners have anything to fear. The loss caused by the tax (and there must, of necessity, be a loss, owing to the moving of the neutral point where the

competition of other countries is met), and the lessened area (a much more serious point than anyone would suppose, unless it has been carefully thought out) over which our coal will be used, must fall on the country generally. This seems to be an effect which no one has anticipated, but it will be found to be true in practice. The great reason which has been in people's minds and has caused them to advocate the tax is that it will, as they think, tend to make the price of coal lower for home consumption, but this, for the reason given above, it will not do in the long run, though probably it will greatly interfere with trade for the next two years. So far, prices (except in South Wales, and that probably for a small quantity outside contracts) have not attained anything like the height which they reached in 1872. In the long run, the 1872 prices caused serious losses in the trade, by attracting too much capital into the business, a large proportion of which was lost. If a sufficiently high price was always obtainable for coal to ensure a fair profit on the outlay, more capital would be invested at home, instead of being put into gold-mines and other similar undertakings abroad, where the risk is even greater than in coal-mining at home.

Another very important question which is prominently before us is that of the eight hours' bank-to-bank day. And the question crops up, "On whom will the burden of this fall?" My reply is, that it will not be on the coal-owner, should the Act be passed limiting the hours during which a fullgrown man shall be underground; and it is scarcely conceivable that this can happen in the twentieth century—the more especially considering the safety and healthiness of those employed in mines. It seems to me that until matters have adjusted themselves, the burden must fall on the consumer; probably this will cause existing collieries to make somewhat more than ordinary profits till more capital has been attracted into the business. Then, for a time, as usually happens, the profits will be nearly *nil*, owing to over-production, and finally matters will settle down just as now, and there will be similar fluctuations in prices and profits, though the former will necessarily average a higher rate, with shorter hours, other things being equal.

In dealing with this matter, it must be borne in mind that the risk of accident for the same output of coal must be greater.

There must be a larger number of journeys in the shaft for the same output, and a much greater aggregate distance travelled by the men to get to their working-places; these matters will throw more responsibility, as is nearly always the case in any change which takes place in existing conditions, on us, as mining-engineers, and we must be prepared to meet them as they arise, that is, should the Bill be passed.

To illustrate my meaning I may take the case of a colliery which comes under my own observation. The pits are 1,650 feet deep, and the day-shift consists of an average of 500 men. The men go down 20 at a time, so that there are 25 runs, and the time taken in letting them down is just in excess of 30 minutes. The average time that a man is in the mine, at present, is 9 hours, including ½ hour for a meal, but what will happen with a working-day of 8 hours, from bank to bank? It will take the same ½ hour to send down the men, and those first going down must begin to ascend 2 minutes before the eighth hour, so that theoretically there will only be 7 hours and 28 minutes of coal-drawing. This calculation assumes that every man comes to bank in the exact order that he went down; and it seems to me that 7¼ hours will be the utmost time, in practice, that such a pit will be able to wind coal, instead of 8 hours as at present, and this with no allowance for a meal.* The result will be, if other things are equal, that only 29/32 of the coal can be produced that is now capable of being drawn, or say 10 per cent. reduction, which means on this colliery nearly 35,000 tons per annum. The trade of the district, in which this colliery is situated, demands to a great extent coal for domestic purposes; and, over a series of years, the average number of days during which coal is drawn per week will not exceed 4, so that the average drawing-hours per week, if the Bill proposed is carried through unaltered, on which these pits will have to subsist will be 29. In other words, in order to draw the same weight of coal, practically, 8 men will have to descend, walk to their work, return and ascend, where 7 men are now required for the same output.

As explained in my address last year, in every decade (and that is the cycle over which for the past century, the good and bad

* There is also a difficulty respecting the hours of boys working on the surface, as the Coal-mines Regulation Act provides that they must have a meal-time, but this may, for the present, be omitted from the calculation.

trade have been most equally distributed), there are four years in which a loss, or at any rate, no profit is made, two when collieries are slightly more than able to hold their own, and four good years; the latter are not all alike, as during the third and fourth year trade is always declining.

Now, to put such a colliery down at the present time, equip it, and find working capital, £200,000 will be required, and at the lowest computation, to replace the capital, and pay interest a return of 10 per cent. should be made each year. This means that a profit of £200,000 should be divided over the four good years, or £50,000 each year, which on the existing output, has been at the rate of 3s. 4d. per ton, but if the 8 hours' limit is enacted, it will be 3s. 10d. You will readily understand from my previous remarks that coal-owners are merely toll-collectors: if they collect more than they should others enter the business and compete with them, and on the other hand, if they cannot collect enough, or, rather as soon as their profits fall till they are conspicuous by their absence, no one thinks it worth while to compete with them till their profits are enhanced; and then the whole cycle is repeated.

Great stress has been laid by the Chancellor of the Exchequer on the difference in the results between the years 1897 and 1900, but I do not think that he remembers that many collieries in 1897 paid no dividend (as well as in 1894, 1895 and 1896), and, in addition, were not able to set aside anything as a provision for the exhaustion of their coal. For 1897, the Chancellor of the Exchequer, in one of his Budget speeches, says that the output, say 220,000,000 tons, at 5s. 7d. per ton amounts to £61,416,666 while the wages of 780,000 men at £1 5s. 0d. per week, amounts to over £50,700,000, leaving less than £11,000,000, or only 1s. per ton to pay for coal used, timber, stores, horse-keep, machinery, interest on capital, management, sales, rates and taxes (this item alone is nearly 2d. per ton), so that it must be admitted that there was, on the whole, a loss during that year.

The Chancellor of the Exchequer's figures for 1900 are:—780,000 men at £1 13s. 4d. per week amounts to £67,600,000, while the sale-value of 220,000,000 tons at 10s. 9½d. per ton is £118,708,333, a difference of £51,108,333. The coal consumed at the collieries, timber, royalty, and all other expenses at the colliery, including management, sales and bad debts, and also

in this year, workmen's compensation, cannot cost, at an average, much under 2s. 6d. per ton, say, £27,500,000, leaving a profit of £23,764,333. But this amount has also to pay for the replacement of capital, after the minerals are exhausted, and deducting 5 per cent. for this charge on the capital value of the collieries (the Chancellor of the Exchequer puts the value at £110,000,000, but it should, in my opinion, be rather more than this amount) or £5,500,000, leaves £18,264,333 for profit or, in a most exceptional year, slightly over 16 per cent. This amount has, however, to help to make up for losses and depreciation in the years 1893 to 1897. During 1900, owing to a greater demand for coal, more expensive seams were worked than in 1897, and this should also be added to the cost. Of course, neither the figures given of the output, nor the number of men employed were in 1897 as much as stated, but the figures are relatively correct, and tend to show that over a series of years coal-mines do not yield a return of 5 per cent., if as much, on the outlay—a sum hardly sufficient to pay for the risk.

The only possible conclusion is that those who invest in collieries are looked upon either as philanthropists, who, as soon as they make up for previous losses, must be taxed, or else unbusinesslike men, especially when they can buy preference shares in good industrial companies to pay this rate of interest. The burden of the eight hours' day, in the long run, however, must fall on the men, because, as I am trying to explain, capital will not be put into a business without a fair return, commensurate with the risk; and the competition with other countries, both in coal and iron, must limit the price.

Collieries, from being deeper, must cost more to sink and develop, so that it will take a much larger sum to pay interest on the capital involved, and the shorter hours must (other things being equal) reduce the output, so that the sum required for interest must be at an enhanced rate per ton. The cost of the change in the district, to which I refer, will be a fair average of other districts; some will, however, suffer more.

A Welsh coal-owner, who has had great experience, has stated that, at his colliery, they were putting by all beyond 10 per cent., as before two years were over, they should be losing £10,000 per annum.

Members will probably ask themselves "Whether these subjects are of interest to mining-engineers?" My reply is that it rests on us to provide for all eventualities, and that we will be expected to try not so much for the sake of the coal-owners, but for the sake of the Government, British trade and the workmen employed, to provide fresh appliances and arrangements whereby in the future, coal may be sold as cheaply as in the past. This will, however, not be an unmixed good, as consumers will then, as in the past, take very little care to economize, so long as they can get coal at all, and, as I remarked at the Bristol meeting in September last, they much prefer to grumble.

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Mr. M. H. Mills (Mansfield), in proposing a vote of thanks to the Chairman, said that his address dealt in an able manner with most of the "burning questions" of the day, but there were one or two points which had not been touched upon. One of these was the dividing of the country into districts for the distribution of electrical power, which would have a considerable effect on coal-mining and it was to be hoped might tend to limit the increasing cost of production. Another subject worthy of mention at a meeting of this kind was the Mond gas process, of which a good deal had been heard in Parliament during the present session. This process would utilize the cheaper kinds of coal, and no doubt it would afford a power by means of gas-engines, which was now obtained by using a good coal for steam-power.

Mr. S. F. Walker (London) thought nobody would misunderstand him when he stated that he was confident collieries were—possibly in the not far distant future—going to be wholly worked by electrical power; but his view was that owners of large collieries or groups of collieries would be able to generate their own current much cheaper than any power-company taking charge of any special district could possibly do. He understood that the cost of current to be supplied by the various district power-distributing companies had been quoted at about 1d. per unit, which represented approximately 1d. per horsepower in the motor. If a plant was properly laid out at a colliery of any size, the cost should not exceed ½d. per unit. In America, the great railways only paid ¼d. (½ cent) per unit, and in many respects this country possessed advantages which America had not.

Mr. J. G. WEEKS (Bedlington), in seconding the vote of thanks to the Chairman for his address, said that he did not wish it to be accepted that the Miners' Eight Hours Bill would decrease the output of coal only by 10 per cent. In Northumberland, where a double shift of hewers was employed and coal was drawn for 10 and 11 hours, the effect of such a bill would be to reduce the output by at least 30 per cent., which would enormously increase the cost of working coal. The passing of the bill would, in his opinion, be much more disastrous than many of them feared the present Finance Bill would be, and which, as they all knew, would hit Northumberland, Scotland and Wales harder than any other districts. He was personally connected with collieries, which exported 80 to 90 per cent. of their produce, and various gentlemen had suggested that the owners were not getting all out of the foreigner that they could get—he could assure them that was not so in his case. The export-duty, after the expiration of existing contracts, and unless there was some change which could not be foreseen, would cause the more expensive collieries to be closed. The colliery-owner would suffer severely, but in the case of the workmen, it would not only diminish their bread and butter but actually remove the bread itself. Sir James Joicey had given some interesting figures in the *Times*,* which showed that the average profit for the last fifteen years did not exceed 8½d. per ton, on the assumption that the expenses other than wages did not exceed 1s. 6d. per ton. He (Mr. Weeks) thought that 1s. 9d. would be much nearer the actual cost under this head than 1s. 6d.; and when 8½d. was assumed, they were talking an average of good, bad and indifferent collieries; some collieries of course made more, but even last year there were many whose profits were small, and he thought there was no doubt that the infliction of the export-duty of 1s. per ton would cause the more expensively worked collieries to be closed.

The question of timbering had been fully discussed, and mining-engineers in the North of England would like to see other people adopt their system instead of their being compelled to adopt unsuitable systems. They claimed that the "deputy system" was superior to other systems, and even superior to that adopted in Staffordshire.

* May 2 nd, 1901, page 12.

The CHAIRMAN (Mr. H. C. Peake), in acknowledging the vote of thanks, which was cordially adopted, agreed that the Miners' Eight Hours Bill and the coal-tax would tell hardly on the North of England, Scotland and South Wales, and said that there must of course be some districts that would be worse hit than the one to which he had specially referred in his address. He concurred with Mr. Weeks in thinking that, for a time at least, the more expensively worked collieries would be closed.

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Mr. M. EISSLER's paper on "The Production of Copper and its Sources of Supply" was read as follows:—

# THE PRODUCTION OF COPPER AND ITS SOURCES OF SUPPLY.

By M. EISSLER.

## 1.—Introduction.

The advances made in the metallurgical treatment of copper-ores are in proportion to the great strides which have been made in other departments of the industrial arts and sciences during the past century, and the limit of improvements has not been reached yet, as the continued efforts to ameliorate the plants at numerous mines tend to lower the cost of production. The tendency of the metallurgist is to work in the direction of rapid treatment of the ores, and to invent methods whereby he can obtain the metallic copper with the least amount of tedious and costly manipulations. The marvellous success that has already been accomplished is shown by the results attained at Lake Superior, where ores containing ½ per cent. of copper can be treated at a profit. Of course, in this case, the simplicity of the metallurgical operations required, to make the copper-contents of the ores marketable, has wonderfully assisted the metallurgist in his operations.

There is a striking difference in a modern copper smelting-plant, when compared with those which were in operation 20 or 30 years ago. A 30 to 50 tons cupola was then considered a large furnace, whereas, if the notable copper-mines of to-day are passed in review, it will be found that the up-to-date water-jackets are smelting, year-in-and-year-out, from 200 to 250 tons and even 300 tons daily. The same comparison applies to reverberatory smelting-furnaces, whose ancestors can be seen in Swansea, where tradition and custom have adhered to the original size of 9 feet by 15 feet internal dimensions, whereas a modern reverberatory furnace has a hearth of 16 feet by 35 feet, smelting

50 tons of ore daily; and even these are small, when compared with those lately erected at the Boston and Montana Company's works, where regenerating reverberatory furnaces are smelting from 125 to 150 tons of roasted ore into matte daily.

It is not only in the direction of capacity and size that advances have been made, but also in the simplification of the processes of extraction. Let any student on the subject take up old text-books and compare the many and varied manipulations through which the ores, matte and the great nomenclature of intermediate products had to pass before fine copper was obtained, with the simplicity of manipulation of the modern metallurgist, obtaining the same results in two or three operations. These resolve themselves practically into converting the raw or the roasted ores into a liquid condition—by smelting—and the conversion of the resulting matte, by bessemerizing, into metallic copper.

The most notable advance in smelting has been the utilization of the sulphur, iron, and other oxidizable substances in the ores as generators of heat, so that they practically smelt themselves, without the aid of extraneous heat: the application of this principle is known as "pyritic smelting."

All copper is not produced by smelting: in some isolated cases, as at Rio Tinto, in Spain, the copper-contents are extracted by wet methods or leaching; and in Arizona, U.S.A., sulphuric acid is used as a solvent for the extraction of copper. The brilliant results achieved at the Rio Tinto mines, by the natural decomposition of the ores, which after being exposed in immense heaps to atmospheric agencies, are then lixiviated, goes to prove that where local conditions favour the introduction of wet methods, copper can be won at a very low cost by these means, and although no exact data are at hand, it is wellknown that the Rio Tinto mines produce copper at about £20 per ton or 2½d. (5 cents) per pound, and no doubt there are many low-grade deposits which can be made remunerative by the application of hydro-metallurgical processes.

Where copper-ores are mixed with a large proportion of earthy ingredients, these are removed by mechanical means, called concentration, and the enriched products or "con-

centrates" are turned over to the smelter. This method is employed at Lake Superior, Butte (Montana) and at some mines in Arizona, U.S.A.

There is a wide field open for investigation in devising a profitable method of treatment of zinciferous copper-ores—by which the zinc is collected and the residues are treated for copper. Large quantities of copper-ores are neglected, because they carry from 25 per cent. and upward of zinc, and the smelters charge a heavy penalty for ores carrying over 8 or 10 per cent. of zinc, the charge being 2s. 1d. (50 cents) per unit of zinc, above this legal minimum.

Owing to the increased demand for fine copper, the large producers refine their product electrolytically; and when the ores carry gold and silver, the separation of these precious metals is effected during this process, and they are collected in the separating-vats and made marketable by wellknown methods.

The principal supply of copper is derived from the United States, which country furnishes over 55 per cent. of the world's production. In that country the methods of treatment have made the most marked advance, and it is matter for reflection that in the United States, where the ruling wages are higher, supplies dearer than elsewhere, and distances to markets are enormous, the producers of copper have been able to control the markets of the world and to compete with mines which are more favourably located.

Many copper-mines prove profitable owing to the precious metals in their ores, and in some instances it is doubtful whether the mines could have been made to pay, in the absence of their gold and silver contents. Such mines as the Le Roi and neighbours, in the Rossland district of British Columbia, could be called gold-mines, as the output at the Le Roi, for 1898, was about 825 tons of copper, 68,000 ounces of silver and 52,850 ounces of gold. The Anaconda mine, Montana, U.S.A., produced in the same year over 5,000,000 ounces of silver and 16,610 ounces of gold. Such mines as the United Verde in Arizona, U.S.A., the Mount Lyell in Tasmania, the Great Cobar in New South Wales, and many others, carry gold and silver, which add largely to the profits made out of these mines.

If an ore be taken, which carries 6 per cent. of copper and 6 ounces of silver and something more than traces of gold per ton, the converter bars will average 100 ounces of silver and 6 to 7 pennyweights of gold, or a value of £13 15s. (66 dollars) per short ton of fine copper, and allowing £5 4s. 2d. (25 dollars) for electrolytic refining charges, this will leave a profit of £8 10s. 10d. (41 dollars) or 1d. (2 cents) per pound of fine copper produced.

The cost of electrolytic refining ranges from £2 10s. to £4 (12 to 20 dollars) per ton according to localities.

It is a difficult matter to establish the average price at which a pound of copper is being produced, as local conditions vary in each district, and so many factors play an important rôle in raising or lowering its cost of production. The most astonishing feature in the American production is the fact that, in Michigan, metallurgical skill has enabled producers to treat ores at a profit carrying only 0·65 per cent. of metallic copper, equal to 13 pounds of copper to the ton: this at 7½d. (15 cents) per pound is equal to 8s. 1½d. (1·95 dollars) per ton; the mining, concentrating and smelting costs are 4s. 11½d. (1·19 dollars),* leaving a profit of 3s. 2d. (0·76 dollar) per ton of ore, and the copper costs 4·575d. (9·15 cents) per pound.

In large ore-bodies having a width of 20 to 100 feet, the cost of breaking the ore should be low, but it is offset by the expense of timbering, and therefore 12s. 6d. to 16s. 8d. (3 to 4 dollars) per ton for mining costs (including developments) ought to be well within the limits.

At the United Verde mine in Arizona, U.S.A., where the claim is made that copper is being produced under the most favoured conditions in that territory, mining costs per pound of copper should be 1½d. (3 cents) on ores averaging 7 per cent. As the ores are heap-roasted, smelted for matte and bessemerized on the spot, with coke costing £2 10s. (12 dollars) per ton, these operations involve an outlay of about 2·25d. (4½ cents) per pound, and the shipment to the eastern electrolytic refinery 0·50d. (1 cent), making the cost with the refining charges about 4·75d. (9½ cents) per pound, in which figures no account is taken of the gold and silver. With some exceptions, the copper produced by

* This low cost was made at the Atlantic mine in 1895, but the rate is now much higher.

the leading mines in the Lake Superior regions also averages about 4·50d. (9 cents) per pound, and the above figures can be taken as the basis of the cost of copper at the principal centres of production in the United States.

Copper-mining at the prices which rule at present, say 7½d. to 8d. (15 to 16 cents), is very profitable; but the margin of profits in mines which carry no precious metals must have been very narrow, when copper was selling at 5¼d. to 5½d. (10½ to 11 cents) per pound, especially at low-grade mines.*

The fact that in most copper-mines, surface and shallow workings have yielded high-grade oxidized ores, has enabled many mines to give profitable results under the most adverse working conditions; it is the rich surface-ores which have furnished the capital to build railways and construct improved smelters; and when the poorer sulphide-ore zone was reached the road was paved for their economical working. A rich surface-showing on any copper-property may prove most deceptive, and the value of the mine can only be determined when the sulphide-ore zone is reached. In some instances, extensive oxidized ore-bodies occur, which may furnish such ores for years—the Copper Queen mine in Arizona, U.S.A., may be mentioned as an example.

Copper, from a metallurgical point of view, is produced by four different methods, namely: (1) From metallic or native ores, such as are found in the Lake Superior mines, where they are of great purity, and require no other treatment than the ordinary refining† and casting for commercial purposes; (2) copper produced from sulphide-ores by smelting in reverberatory and blast-furnaces, with the attendant preliminary preparation of the ores and the subsequent converting and refining operations; (3) the production of the metal from oxidized ores by a reducing smelting in blast-furnaces with subsequent refining; and (4) the metal is produced from sulphide and oxidized ores by various leaching processes and subsequent precipitation.

The bulk of the metallic copper is produced from low-grade ores, of which some examples are given in Table I.

The production of copper for the world, by countries, for the years 1898 and 1899, the latest years for which detailed records

* Copper was sold at 4 ½d. (9cents) per pound in 1894-1895.

† Smelting to separate the native metal from the gangue.

TABLE I.

| Name of Mine or Company. | Locality. | Copper-content. | Silver. | Gold. |
|---|---|---|---|---|
| | | per cent. | Ounces per ton. | Ounces per ton. |
| Copper Queen ... ... | U.S.A., Arizona .. | 8·000 | — | — |
| United Verde ... ... | do. do. .. | 7·000 | ? | ? |
| Mountain Copper Company | do. California .. | 8·000 | — | — |
| Anaconda ... ... ... | do. Montana ... | 4·260 | 4·16 | 0·014 |
| Atlantic Mining Company | do. Lake Superior | 0·648 | — | — |
| Calumet and Hecla ... | do. do. ... | 3·000 | — | — |
| Kearsarge ... ... ... | do. do. ... | 1·990 | — | — |
| Osceola Consolidated ... | do. do. ... | 1·070 | — | — |
| Quincy Mining Company . | do. do. ... | 1·270 | 2 to 28 | — |
| Tamarack ... ... .. | do. do. ... | 1·330 | — | - |
| Wolverine ... ... ... | do. do. .. | 1·150 | — | — |
| Great Hall ... ... ... | Canada, British Columbia ... ... | 3·470 | — | — |
| Le Roi ... ... ... | do. ... | 2·350 | 1·53 | 0·780 |
| Tilt Cove ... ... .. | Newfoundland ... | 3·500 | — | — |
| Cape Copper ... .. | Cape Colony ... | 10·000 | — | — |
| Great Cobar Copper ... | New South Wales .. | 4·220 | 0·50 | 0·194 |
| Mount Lyell ... .. | Tasmania ... | 3·520 | 2·38 | 0·090 |
| Atacama District ... ... | Chile ... ... | 5·000 | — | — |
| Boleo ... ... . | Mexico ... ... | 6·000 | — | — |
| Mansfeld ... ... .. | Germany ... ... | 2·500 | 5·00 | — |
| Rio Tinto ... ... ... | Spain ... ... | 3·000 | 1·50 | traces. |

TABLE II.—THE WORLD'S PRODUCTION OF COPPER FOR THE YEARS 1898 AND 1899.*

| No. | Countries. | 1898. Tons.† | 1899. Tons. † | Per cent. of total Production 1899. |
|---|---|---|---|---|
| 1 | United States of America ... ... | 239,241 | 259,517 | 55·50 |
| 2 | Spain and Portugal ... ... ... | 53,225 | 54,220 | 11·51 |
| 3 | Japan ... ... ... | 25,175 | 27,560 | 5·90 |
| 4 | Chile ... ... ... ... ... | 24,850 | 25,000 | 5·40 |
| 5 | Germany ... ... ... ... | 20,085 | 23,460 | 4·90 |
| 6 | Australasia ... ... ... ... | 18,000 | 20,750 | 4·40 |
| 7 | Mexico ... ... ... ... ... | 15,668 | 19,121 | 4·17 |
| 8 | Canada ... ... ... .. ... | 8,040 | 6,730 | 1·40 |
| 9 | South Africa ... ... ... ... | 7,060 | 6,490 | 1·37 |
| 10 | Russia ... ... ... ... | 6,000 | 6,000 | 1·30 |
| 11 | Peru ... ... ... ... ... | 3,040 | 5,165 | 1·10 |
| 12 | Norway ... ... ... ... ... | 3,615 | 3,610 | 0·78 |
| 13 | Italy ... ... .. ... | 3,039 | 3,000 | 0·64 |
| 14 | Newfoundland .. ... ... ... | 2,100 | 2,700 | 0·56 |
| 15 | Bolivia ... ... ... ... ... | 2,050 | 2,500 | 0·50 |
| 16 | Austro-Hungary ... ... ... | 1,540 | 1,505 | 0·33 |
| 17 | United Kingdom ... ... ... | 640 | 550 | 0·24 |
| 18 | Sweden .. ... ... ... | 480 | 520 | |
| 19 | Argentina .. ... ... ... | 125 | 65 | |
| 20 | Algeria ... ... ... ... ... | 50 | 0 | |
| | Totals | 434,023 | 468,463 | — |

* Compiled from *The Mineral Industry*. † Tons of 2,240 pounds.

are obtainable, is recorded in Table II. The quantity of 468,463 tons (Table II.) at an average price of £60 per ton represents a value of £28,107,780. It would be interesting to ascertain the

TABLE III.—LIST OF THE PRINCIPAL MINES AND THEIR PRODUCTION FOR 1899.

| No. | Name of Mine. | Country. | Tons.* |
|---|---|---|---|
| 1 | Anaconda ... ... ... | Montana, U.S.A. ... ... | 48,176 |
| 2 | Calumet and Hecla ... .. | Lake Superior, U.S A. ... .. | 43,750 |
| 3 | Rio Tinto . ... | Spain ... ... ... .. | 33,882 |
| 4 | Boston and Montana ... ... | Montana, U.S.A. ... ... | 30,000 |
| 5 | Mansfeld ... .. .. | Germany ... ... ... | 20,785 |
| 6 | United Verde ... ... ... | Arizona, U.S.A. .. . | 19,641 |
| 7 | Copper Queen ... ... | Do., do. .. .. | 16,473 |
| 8 | Tharsis ... ... ... ... | Spain ... .. ... .. | 12,000 |
| 9 | Boleo ... ... ... ... | Mexico ... ... .. ... | 10,335 |
| 10 | Iron Mountain .. ... ... | California, U.S.A. ... .. | 10,000 |
| 11 | Arizona Copper Company .. | Arizona, U.S.A. . ... | 8,514 |
| 12 | Tamarack ... ... .. | Lake Superior, U.S A. ... . | 7,924 |
| 13 | Mount Lyell ... ... .. | Tasmania ... ... ... .. | 7,600 |
| 14 | Montana Ore-purchasing Company ... ... ... ... | Montana, U.S.A. ... | 6,857 |
| 15 | Besshi ... ... ... ... | Japan ... ... ... ... | 8,000 |
| 16 | Ashio ... ... ... ... | Do. .. .. ... ... | 6,500 |
| 17 | Quincy Mining Company ... | Lake Superior, U.S.A. .. | 6,384 |
| 18 | Butte and Boston .. ... | Montana, U.S.A. ... .. | 5,267 |
| 19 | Detroit Company ... ... | Arizona, U.S.A. ... .. | 6,208 |
| 20 | Wallaroo and Moonta | South Australia .. ... | 5,073 |
| 21 | Osceola Consolidated ... ... | Lake Superior, U.S.A. .. ... | 4,888 |
| 22 | Parrot Mining Company .. | Montana, U.S.A. ... | 4,743 |
| 23 | Butte Reduction-Works ... | Do, do. ... ... | 4,486 |
| 24 | Colorado Smelting and Refining Company ... .. ... | Do., do. ... .. | 4,273 |
| 25 | Cape Copper Company . ... | Cape Colony ... ... .. | 4,140 |
| 26 | Mason & Barry, Limited ... | Portugal ... ... ... | 4,000 |
| 27 | Great Cobar ... ... ... | New South Wales ... ... | 3,520 |
| 28 | Utah Consolidated ... .. | Utah, U.S.A. ... ... ... | 3,487 |
| 29 | Old Dominion ... ... ... | Arizona, U.S.A. .. ... | 2,811 |
| 30 | Sudbury .. ... ... ... | Canada ... ... .. ... | 2,738 |
| 31 | Namaqua Copper Company ... | Cape Colony ... ... ... | 2,350 |
| 32 | Rossland ... .. ... ... | British Columbia, Canada .. | 2,336 |
| 33 | Wolverine ... ... ... | Lake Superior ... .. .. | 2,137 |
| 34 | Atlantic ... ... ... ... | Do. do. ... ... .. | 2,087 |
| 35 | North Mount Lyell ... ... | Tasmania ... . ... | 2,000 |
| 36 | United Globe ... ... ... | Arizona, U.S.A. ... ... ... | 1,987 |
| 37 | Nelson .. ... ... ... | British Columbia, Canada ... | 1,873 |
| 38 | Tilt Cove ... ... . ... | Newfoundland ... .. ... | 1,800 |
| 39 | Kiadabek ... ... ... | Russia .. ... ... .. | 1,800 |
| 40 | Franklin .. ... ... ... | Lake Superior, U.S.A. ... ... | 1,600 |
| | | TOTAL | 372,435 |

* Tons of 2,240 pounds.

quantity of silver and gold contained in the copper produced, but as many mine-owners refuse to give the necessary data it is impossible to make such a computation. The eleven electrolytic

copper-refineries in the United States have an estimated annual yield of 198,600 tons of copper, 170,273 ounces of gold and 21,199,200 ounces of silver; taking the gold at £4 per ounce and silver at 2s. 6d. (60 cents) per ounce, this represents £3,225,000 or an average of £16 5s. of gold and silver per ton of copper treated, although no doubt these values fluctuate very largely according to localities.

Table III., carefully compiled from the official reports of the companies, gives the production of the world's largest mines for the year 1899. There are several other producers, no doubt, of 1,600 tons yearly, but the data were not obtainable. The first 10 mines in Table III. produce 48 per cent. of the world's output, and the other 30 mines supply 30 per cent., leaving 22 per cent. to the mines not enumerated.

Most mines are being pressed into greater activity to increase the output, with the result that the copper-production during the last 2 or 3 years of the past century was the largest in the history of this metal; and in spite of the discovery and development of new copper ore-bodies and the activity of existing producers, they are barely keeping pace with the increasing demand for this metal. The best authorities on the subject seem to agree that the price of copper will be maintained at its present level, and the principal argument which is brought forward in support of this theory is that many of the great copper-mines cannot maintain indefinitely their present ratio of production, and that there are at present very few new large ore-bodies being developed that promise to become large sources of supply in coming years. The general opinion is that eventually any reduced output from the large mines will be equalized by the production of numerous smaller properties which are in course of development.

No doubt, the great prosperity and activity in the United States, which will continue under the present administration, will contribute to the maintenance of the present price of copper, and it is not likely that for the next three years any considerable fall will take place, but the coming presidential election will act as a disturbing factor in the metal market, irrespective of the economic conditions of that country.

The following figures prove that the increase in the world's production is not large: in 1899, the production was 468,463 tons; whereas, in 1898, it amounted to 434,023 tons, showing an increase of only 34,440 tons, or 7½ per cent; further in 1900, the production was 486,084 tons; whereas, in 1899, the production was 468,463 tons, an increase of 17,621 tons or barely 4 per cent. From these figures it may be inferred that an over-production of the metal is not likely to take place, in view of the increasing demand which exists for electrical, naval and railway purposes.

TABLE IV.—THE WORLD'S PRODUCTION OF COPPER SINCE 1879.

| Year. | Tons.* | Year. | Tons.* | Year. | Tons.* |
|---|---|---|---|---|---|
| 1880 | 153,959 | 1887 | 223,798 | 1894 | 324,764 |
| 1881 | 163,369 | 1888 | 258,026 | 1895 | 334,554 |
| 1882 | 181,622 | 1889 | 261,205 | 1896 | 378,440 |
| 1883 | 199,406 | 1890 | 269,615 | 1897 | 405,350 |
| 1884 | 220,249 | 1891 | 275,589 | 1898 | 434,023 |
| 1885 | 225,592 | 1892 | 291,474 | 1899 | 468,463 |
| 1886 | 217,086 | 1893 | 302,021 | 1900 | 486,084 |

* Tons of 2,240 pounds.

TABLE V.—CONSUMPTION OF COPPER IN DIFFERENT COUNTRIES IN 1899.*

| Countries. | Tons. |
|---|---|
| United States of America (outside of existing stocks) ... ... | 190,887 |
| Germany ... ... ... ... ... ... ... ... ... | 97,656 |
| Great Britain ... ... ... ... ... ... ... ... ... | 82,404 |
| France ... ... ... ... ... ... ... ... ... | 47,633 |
| Austro-Hungary ... ... ... ... ... ... ... | 16,921 |
| Russia ... ... ... ... ... ... ... ... ... | 12,500 |
| Italy .. ... ... ... ... ... ... ... ... | 8,520 |
| Belgium .. ... ... ... ... ... ... ... ... | 5,500 |
| Netherlands ... ... ... ... ... ... ... ... | 2,400 |
| Denmark, Sweden, Norway, Spain, and Balkans ... ... | 2,600 |
| Exportation to Asia and other Countries ... ... ... ... | 1,250 |
| Japan, Australasia, and Eastern Asia ... ... ... ... | 9,000 |
| Total Consumption ... .. | 477,271 |

* *Recueils Statistiques*, by the Metallgesellschaft, Frankfurt-am-Main, 1900.

TABLE VI.—STOCKS OF COPPER ON HAND IN FRANCE AND GREAT BRITAIN, EXCLUDING COPPER IN TRANSIT FROM CHILE AND AUSTRALIA, ACCORDING TO REPORTS BY MESSRS. H. R. MERTON AND COMPANY, LONDON.

| Year. | Stocks on Jan. 1st. Tons. | Year. | Stocks on Jan. 1st. Tons. |
|---|---|---|---|
| 1888 ... ... | 35,001 | 1895 ... ... | 51,575 |
| 1889 ... ... | 96,194 | 1896 ... ... | 43,604 |
| 1890 ... ... | 94,942 | 1897 ... ... | 31,776 |
| 1891 ... ... | 62,449 | 1898 ... ... | 27,895 |
| 1892 ... ... | 53,486 | 1899 ... ... | 22,702 |
| 1893 ... ... | 51,556 | 1900 ... ... | 17,797 |
| 1894 ... ... | 43,428 | 1901 ... ... | 12,600 |

If we take in consideration the production of copper for the past five years from 1896 to the end of 1900, it will be found that

it has increased from 378,440 tons to 486,084 tons, or at the rate of about 5 per cent. per annum; and, during that period, the consumption has kept pace with this production. Taking this basis of 5 per cent. per annum as representing the increase of copper-consumption during coming years, the quantities of copper that will have to be produced at the beginning of this century are recorded in Table VII. Consequently at the present ratio of increase, 14 years hence, the consumption of copper will have doubled; which is quite in keeping with the record of the past 14 years. In 1887, the production was 223,798 tons, whereas in 1900, it had increased to 486,084 tons.

TABLE VII.—ESTIMATE OF THE WORLD'S PRODUCTION OF COPPER IN THE TWENTIETH CENTURY.

| Year. | Tons.* | Year. | Tons.* |
|---|---|---|---|
| 1901 | 510,392 | 1908 | 730,945 |
| 1902 | 535,911 | 1909 | 767,492 |
| 1903 | 572,706 | 1910 | 806,866 |
| 1904 | 601,341 | 1911 | 847,209 |
| 1905 | 631,418 | 1912 | 889,559 |
| 1906 | 662,988 | 1913 | 934,036 |
| 1907 | 696,137 | 1914 | 980,737 |

* Tons of 2,240 pounds.

At the present price of copper, which can be taken on an average of £60 per ton, there is a handsome margin of profit in mines which can produce the metal at £40 per ton; and a mine which can turn out 1,000 tons of copper a year would show a profit of £20,000, which amply justifies the investment of capital in copper-mines.

In studying the question of supply and demand. it would be interesting to present such facts as would embody the future possibilities of all the prominent mines with regard to their ability to maintain or increase their present output of copper, which is not within the scope of this paper. Some general remarks on the subject are offered, and they embrace only the districts where notable copper-mines are located.

Although copper-ores are found distributed over the whole world, the chief centres of the great producers are not very numerous, if it be considered that Montana, Michigan and Arizona, U.S.A., and Spain and Portugal, account for 285,939 tons or more than 61 per cent. of the total production. The United States is the largest copper-producing country, next in importance are Spain and Portugal, then comes Chile, whose production

stands about equal with Japan's, and next in importance is Germany, followed by Australasia and Mexico.

There is very little doubt that the ore-bodies of Butte, Montana, U.S.A., will extend to great depth;* it is questionable whether they will maintain their present copper-values, but with improved methods they will be able to maintain their present production for many years.

The deposits of Lake Superior, U.S.A., are of great extent and are known to exist at great depths.† The conclusion can be drawn that the supply from that region will be maintained, and possibly, owing to the increase in the price of the metal, as new and old mines are being opened, the present ratio of production in that region will increase.

TABLE VIII.—AVERAGE PRICE OF COPPER.

| Year. | Chile Bars, G.M.B., per Ton* in London. | | | Lake Copper in New York. | | | |
|---|---|---|---|---|---|---|---|
| | | | | Per Pound. | Per Ton. | | |
| | £ | s. | d. | Cents. | £ | s. | d. |
| 1888 | 81 | 11 | 3 | 16⅔ | 77 | 0 | 0 |
| 1889 | 49 | 14 | 8 | 13¾ | 63 | 10 | 0 |
| 1890 | 54 | 5 | 3 | 15¾ | 72 | 15 | 0 |
| 1891 | 51 | 9 | 4 | 12⅞ | 59 | 10 | 0 |
| 1892 | 45 | 13 | 2 | 11½ | 53 | 0 | 0 |
| 1893 | 43 | 15 | 6 | 10¾ | 49 | 10 | 0 |
| 1894 | 40 | 7 | 4 | 9½ | 43 | 15 | 0 |
| 1895 | 42 | 19 | 7 | 10¾ | 49 | 10 | 0 |
| 1896 | 46 | 18 | 1 | 10⅞ | 50 | 17 | 6 |
| 1897 | 49 | 2 | 7 | 11⅓ | 52 | 5 | 0 |
| 1898 | 57 | 16 | 7 | 12 | 55 | 15 | 0 |
| 1899 | 73 | 13 | 9 | 17⅝ | 81 | 7 | 6 |

* Tons of 2,240 pounds.

The Rio Tinto mines are of such known extent that the present production will be maintained for some generations to come.

Judging from indications as they present themselves to the observant copper-prospector, it is more than likely that a few years hence, Arizona, U.S.A., will greatly increase its present production. Mexico will, given the necessary railway facilities, more than double its present production.

Although Colorado, U.S.A., figures as a copper-producer, the

* The values of the Butte ore-bodies decrease in depth.

† The Tamarack No. 5 shaft has attained a depth of 4,950 feet.

metal is won mostly as a bye-product in the treatment of its silver-lead and other ores, and from the copper-ores sent to the custom-smelters from various quarters of the Western States.

Besides Shasta county, other counties in California, U.S.A., promise to become producers of copper; and in Idaho, U.S.A., when railway-communication has been established with the Seven Devils country, some valuable copper-deposits will become available. Wyoming, as well as Nevada, U.S.A., will also be added to the list of copper-producers. Utah, U.S.A., too, has some valuable copper-mines.

Recent discoveries of alluvial gold in Alaska, U.S.A., have given an impetus to prospecting in that Arctic region; the reports of copper-discoveries from there are too numerous to be ignored; but so far attention has only been given to properties which are located near the sea-coast. When a railway-line connects Walfisch Bay, with the Cape-Town to Bulawayo line, something will be heard of the now dormant deposits of copper in German South-west Africa. New Caledonia is shipping, at present, its ores to various ports of Australia, but no doubt in course of time, it will have its own smelting-establishments. In Brazil, a French company is inaugurating work on some promising mines which are favourably located for economical exploitation.

There is no telling where new discoveries may be made, and consequently such a contingency as an exhaustion of the copper-supply in a generation or two is not likely to take place, for many localities which are copper-bearing will become productive when provided with railway and transport facilities; but so far there is no indication that overproduction can take place in the near future.

The development of the copper-mining industry in the Western States of America and in Mexico is greatly assisted by custom-smelters who have a very uniform rate of charges, according to location; and it will be interesting to examine Table IX., containing a schedule of the smelting-charges of one of the Arizona smelters, located at the Needles.

The zinc limit in lead-ores and copper-ores is 10 per cent., and for each unit over and above 10 per cent., 2s. 1d. (50 cents) per unit is the penalty.

The payment for lead, above 5 per cent., per unit on a 16s. 8d.

(4 dollars) basis, New York price, is shewn in Table X., and for each advance or decline of 2½d. (5 cents) in the New York price, a corresponding variation of ½d. (1 cent) is made in the price per unit.

Sulphur up to 5 per cent. is allowed free in copper-ores, but 1s. 0½d. (25 cents) per unit is charged for the excess above it.

The smelting-rates on copper-ores are shown in Table XI.

Neutral bases, such as silica and iron, are charged 7½d. (15 cents) per unit up or down to a maximum charge of £2 12s. 1d. (12·50 dollars) per ton.

TABLE IX.

| Copper-ores containing Lead. Percentages. | Smelting-charge per Ton. £ s. d. | Dollars. | Copper-ores containing Lead. Percentages. | Smelting-charge per Ton. £ s. d. | Dollars. |
|---|---|---|---|---|---|
| 0 to 5 | 2 12 1 | 12·50 | 30 to 35 | 1 7 1 | 6·50 |
| 5 ,, 10 | 2 7 11 | 11·50 | 35 ,, 40 | 1 2 11 | 5·50 |
| 10 ,, 15 | 2 3 9 | 10·50 | 40 ,, 45 | 0 18 9 | 4·50 |
| 15 ,, 20 | 1 19 7 | 9·50 | 45 ,, 50 | 0 14 7 | 3·50 |
| 20 ,, 25 | 1 15 5 | 8·50 | 50 ,, 60 | 0 10 5 | 2·50 |
| 25 ,, 30 | 1 11 3 | 7·50 | 60 and over | — | free. |

TABLE X.

| Copper-ores containing Lead. Percentages. | Payment per Lead Unit. s. d. | Cents. | Copper-ores containing Lead. Percentages. | Payment per Lead Unit. s. d. | Cents. |
|---|---|---|---|---|---|
| 0 to 5 | nil | nil | 30 to 35 | 2 1½ | 51 |
| 5 ,, 10 | 1 8 | 40 | 35 ,, 40 | 2 2½ | 53 |
| 10 ,, 15 | 1 8 | 40 | 40 ,, 45 | 2 2½ | 53 |
| 15 ,, 20 | 1 8 | 40 | 45 ,, 50 | 2 3 | 54 |
| 20 ,, 25 | 1 8½ | 41 | 50 ,, 60 | 2 3½ | 55 |
| 25 ,, 30 | 2 1 | 50 | 60 and over | 2 3½ | 55 |

TABLE XI.

| Percentages of Copper. | Smelting-charge per ton. £ s. d. | Dollars. | Percentages of Copper. | Smelting-charge per ton. £ s. d. | Dollars. |
|---|---|---|---|---|---|
| 0 to 5 | 1 13 4 | 8·00 | 15 to 20 | 1 2 11 | 5·50 |
| 5 ,, 10 | 1 9 2 | 7·00 | 20 ,, 25 | 1 0 10 | 5·00 |
| 10 ,, 15 | 1 5 0 | 6·00 | 25 ,, 30 | 0 18 9 | 4·50 |

TABLE XII.

| Percentages of Copper. | Rate per unit. £ s. d. | Dollars. | Percentages of Copper | Rate per unit. £ s. d. | Dollars. |
|---|---|---|---|---|---|
| 0 to 5 | 0 6 3 | 1·50 | 15 to 20 | 0 8 9 | 2·10 |
| 5 ,, 10 | 0 7 3½ | 1·75 | 20 ,, 25 | 0 8 11½ | 2·15 |
| 10 ,, 15 | 0 8 4 | 2·00 | 25 ,, 30 | 0 9 2 | 2·20 |

The payments for copper-ores are shown in Table XII.

Gold is paid for at the rate of £4 3s. 4d. (20 dollars) an ounce; and silver at 2s. 6d. (60 cents) an ounce.

The western smelters greatly prize lead-ores of a high percentage, and make no smelting-charge for ores containing over 60 per cent. of lead, as this metal is mainly utilized as a collector for the gold and silver contained in the dry ores.

The railway companies charge their freights in accordance with the value of the ores, the low-grade paying lower rates than the high-grade ores.

## 2.—The Occurrence and Distribution of Copper-ores.

### (1) *Arizona, U.S.A.*

Copper-ores are extensively distributed throughout this territory, which in course of time is destined to become the second or even the first in the rank of producers in the United States. At present, the chief centres of production are: Bisbee in the southern portion of Cochise county, Jerome in Yavapai county, Morenci and Clifton in Graham county, and Globe in Pinal county. Large quantities also have been produced in Pima county, near Tucson, and in the Santa Rita Mountains, near Rosemont. With the advent of improved railway-communication many localities will become producing centres, as many promising prospects are idle for lack of capital and transport facilities. Those which deserve to be mentioned are:—The Azurite copper-mines in the Surritas Mountains, Olive Camp in the Pima mining district, the San Xavier mine near Tucson, the Hillside copper-mines in the Eureka district, the Ray copper-mines of Pinal county, the Kennedy-Bryan Group in Pinal county, the Helvetia copper-mines are working steadily, situated 31 miles south of Tucson, the Dos Cabezas mines, the Grand Reefs in Graham county, the Piety group in Pinal county, the Castle Creek district in Yavapai county, and many others.

The production of copper in this territory, for 1899, amounted to over 55,000 long tons.

*United Verde Mines.*—These mines, situated at Jerome, 28 miles from Prescott, in Yavapai county, are owned by Senator Clark of Montana, who built his own railway to connect the mine with the Prescott and Phoenix line. He produces from 1,500 to 1,800 tons of copper monthly, containing considerable quantities of gold and silver. The ore-bodies are of great extent and value, and cannot be exhausted in a lifetime. From different levels, adits have been driven, which have opened the mine to a depth of 600 feet. By one of those strange incongruities peculiar to mine administration, the splendid smelting-works are located on the top of a mountain, and the ore has to be hauled up steep inclines by electric traction, instead of taking advantage of the natural declivity, which would allow of the automatic handling of the ore, if the smelter had been located at the foot of the

mountain, and would have made it also possible to utilize the ample water-supply of the Verde river, not so very far distant from the base of the mountain-range on which this mine is located.

The mines, smelting-plant and town of Jerome are situated on the eastern slope of the Black Hill range, nearly upon the crest, at an altitude of about 5,600 feet above sea-level, and at least 1,800 feet above the Rio Verde valley, which spreads out in a grand panorama to the east and south.

The ore-bodies are found in slates, and to a limited depth the ores were carbonates and oxides. Below the surface-ores is found a partially oxidized rich black sulphide of copper, and below this are found the unaltered sulphide-ores. Most of the ores from this mine are now heap-roasted before going to the smelter. In 1899, the mine produced about 20,000 tons of copper.

*Bisbee.*—The camp is situated near the head of a cañon, on almost the extreme southern edge of Cochise county, about 6 miles from the Mexican boundary-line. The Bisbee mine is owned by the Copper Queen Company. It is reached by its own railway, which connects with the Southern Pacific Railway at Benson, about 35 or 40 miles northwest. The town is scattered up and down the cañon for at least a mile; but the business portion is centred immediately east and south of the smelting-plant.

The ore-deposits occur in limestone, and the appearance of the oxidized ore is very peculiar and to the inexperienced eye would appear like so much clay enclosing nodules of cupriferous limonite. An appreciable quantity of finely divided metallic copper is found disseminated through these clayey ore-bodies. To a depth of 400 feet, the copper is mainly in the form of carbonates with hydrated oxides of iron and alumina, carrying about 8 per cent. of copper, but below this depth sulphide-ores are encountered.

At this mine, copper-bars were produced by a single fusion from the oxidized ores. In 1894, matte-smelting was adopted, but there is still enough oxidized ore in the mine to enrich the matte, which averages 45 per cent. The production of copper from this mine in 1899 was 16,473 tons.

All the copper at the Arizona carbonate-mines is produced

by a single fusion in water-jacket furnaces; and, in case any excess of sulphide-ores are present, a matte is produced simultaneously, which is roasted in kilns and added to the ore-charges. The copper is produced as black copper, containing from 95 to 97 per cent. of copper, and the matte carries 50 to 60 per cent. of copper.

*Clifton Copper District.*—The principal companies engaged in mining in this district are the Arizona Copper Company of Clifton, and the Detroit Copper-mining Company of Morenci. The former company draws its ore-supplies from various groups of mines, situated from 5,000 to 7,000 feet above sea-level. The most important of them—the Longfellow group—is situated in the heart of the Morenci field, side by side with the mines of the Detroit Copper-mining Company, has been a producer since 1872. Up till a few years ago, practically all the ores were taken from the contacts of magnesian limestone and porphyry. These ores were oxidized and self-fluxing, and a single smelting was all that was necessary to produce copper bullion, 98 per cent. fine. The mineralized limestone-belt extended fully 1 mile in length. The ore-bodies, however, were largely superficial in their occurrence, and were never found in quantity at a greater depth than 300 feet below the surface, the average depth of pay-ore being 150 feet. The ores, generally, have been formed by the replacement of limestone by solutions of copper. As early as 1891, the mines situated in the magnesian limestone-field began to give evidence of exhaustion. Extensive exploration by the diamond drill was only successful in exposing and throwing more light on the mineral formation. Exploration for new ore-bodies in this direction being unsuccessful, attention was turned to the extensive porphyry-belt against which the limestone and calcareous shales abut.

On the surface of the porphyry-belt there were practically no indications of copper. There was, therefore, nothing definite to follow from the surface. Under the circumstances, it was deemed advisable to pierce the Humboldt Mountain by a tunnel which would cut under the apex of the mountain at a depth of fully 400 feet. This work, conducted with judgment, was successful in exposing enormous bodies of low-grade sulphide-ores, which, however, were so low in grade that for a time it was

doubtful whether they could be treated with profit. An enormous amount of capital had been sunk in the development of the ore-bodies, and further large outlays were made on concentrating-plants and on other plants necessary for the treatment of these ores. The problem was successfully solved, and the ore-bodies exposed proved much more extensive than the original magnesian limestone-belt.

In addition to the Longfellow group, the company has also groups of mines known as the Queen, Coronado and Metcalf. Of these, the last-named, so far, has been the most important. It has produced largely a low-grade oxidized ore found on the surface of the Metcalf Hill. This ore, while extremely low in grade, occurs in great quantity. For its treatment concentration and leaching have both been found necessary.

Both at Clifton and Morenci, concentration of the carbonate-ores has been carried on; this gave rich concentrates, but the losses in the tailings being heavy, leaching-works have been erected for their treatment by means of sulphuric acid, using metallic iron to precipitate the copper. The acid is made on the spot from the sulphide copper-ores.

The metallurgical plant is one of the largest in the territory, and consists of smelting-furnaces with a capacity of 500 tons per day, concentrating-plant with a capacity of 750 tons per day, a leaching-plant with a capacity of 150 tons per day, a two-converter Bessemer plant, operated entirely by gas-engines; a sulphuric-acid plant and a bluestone plant. In addition to the Bessemer plant, three of the concentrating plants are operated by gas-engines. The gas-engines employed have a rated capacity of 750 horsepower, and have been found to be extremely economical in fuel. The company is now producing copper at the rate of about 9,000 tons per annum. It employs about 1,500 men on its mines, railways and works.

The Detroit Copper-mining Company of Morenci, the property of Messrs. Phelps, Dodge and Company, produces about 6,000 tons of copper per annum and employs 1,000 men. This company is about to build a narrow gauge (3 feet) railroad from Morenci to Guthrie, a distance of 18 miles. The company is also erecting a 100 tons concentrating-plant, and is making many improvements of a substantial order.

*Globe Copper District.*—The Globe district is situated on the north-western slope of the Pinal Mountains, about 28 miles from the old and once famous Silver King mine. In the period from 1876 to 1883, this district attracted much attention by reason of the many discoveries of rich silver-mines. At present mining activity is confined chiefly to copper. The completion of the Gila Valley, Globe and Northern railway, a branch of the Southern Pacific railway, now gives access to the region, and has greatly stimulated its development. The first location on what is now considered the main copper-bearing belt was made in 1875 by the locators of the Silver King mine, and it was named the "Globe." This location is now held and worked by the Old Dominion Copper Company, which also has two other locations on the same vein—the Southwest Globe and the Globe Ledge. The vein is described as following a contact, having a diorite foot-wall and a limestone hanging-wall containing fossils of the Carboniferous period. On the west side of the outcrop, there is a capping of trachyte, which conceals outcrops in that direction. Good ore was proved by Dr. Trippel in a drift west from the shaft, and openings were afterwards made through the bed of trachyte; these have been extended downward in ore for over 300 feet. This deposit was regarded by Dr. Wendt as a fissure-vein, and he notes that in approaching the ore-body through the long adit-tunnel running lengthwise of the claims the conditions were similar to those observed in the Longfellow mines at Clifton and the Queen and Prince mines at Bisbee, especially as regards the decomposition and kaolinization of the rock.

TABLE XIII.—COPPER-PRODUCTION IN ARIZONA, U.S.A., FOR 1898 AND 1899.*

| Names of Mines. | 1898. | 1899. |
|---|---|---|
| | Tons.† | Tons.† |
| Arizona Copper ... ... ... | 8,111 | 8,514 |
| Copper Queen ... ... ... ... | 15,066 | 16,473 |
| Detroit ... ... ... ... ... | 5,102 | 6,208 |
| Old Dominion ... ... ... ... | 800 | 2,811 |
| United Verde ... ... ... ... | 18,896 | 19,671 |
| United Globe ... ... ... ... | 1,271 | 1,987 |
| Other Mines ... ... ... ... | 223 | 334 |
| Totals ... ... | 49,469 | 55,998 |

* Compiled from *The Mineral Industry*. † Tons of 2,240 pounds.

The ores are mostly oxidized, but large bodies of sulphide-ores have been found on the second and third levels, with

oxidized ores below them. The ores carry a large amount of silica and frequently require heavy additions of lime and iron to the smelting-charges.

### (2) *Montana, U.S.A.*

The principal copper camp in Montana is Butte, well known through the famous Anaconda mine. Like a promontory, a butte rises boldly above the surrounding country as a landmark to prospectors, giving this locality in Silver Bow county the name of Butte, which, prior to the development of its copper-resources, was known as a prominent silver-producing camp.

The mining district, around Butte City, forms a rectangle 7 miles long by 4 miles wide. The country-rock is mainly granite, traversed by dykes of volcanic rocks, which seem to be in close association with the eruptive rocks of the Butte. The copper-belt occupies a large portion of this area, and the ore-deposits occur in very irregular masses. They do not seem to have in many places defined walls, and the ore occurs mostly in shoots, which pinch out along the strike, but are very persistent in depth. The ore-formation is a succession of lenses, and this lenticular form is very characteristic of the smaller ore-deposits. The width of the ore-shoots varies, from a few feet up to 100 feet, as in the Anaconda mine.

In these large ore-bodies occur horses and large bunches of country-rock, which, together with the very poor ore, are left behind to fill in the stopes. Like those of most large copper ore-bodies, the outcrop-ores are of brown quartz, heavily charged with iron. After breaking through this quartz-capping, quartz associated with soft red and yellow iron-oxides, rich in gold and silver, occurs, but showing very little copper. On deeper sinking, the copper-zone is gradually approached, and at water-level the unaltered region is finally reached.

As the ore-bodies do not present very sharply defined walls, Mr. S. F. Emmons has suggested that they have been formed along a series of small fissures marking some line of disturbance, and not from a general faulting, and have enlarged the original channels by replacement of the walls.

The mineral characteristics are varying proportions of sulphide of copper, chalcopyrite and pyrite, and occasional bornite. The gangue is mainly granitic with some quartz.

Mr. Hiram W. Hixon, in his *Notes on Lead and Copper-smelting*,* gives the cost of making 1 pound of copper at the Anaconda mine as shewn in Table XIV. This cost does not include freight to New York City. In each pound of copper there is recovered an average value of about 2d. (4 cents) in precious metals.

TABLE XIV.

| | Per Pound of Copper Sold. Pence. | Cents. |
|---|---|---|
| Mining ... ... ... ... | 1·556 | 3·112 |
| Concentrating ... ... | 0·307 | 0·614 |
| Smelting ... ... ... | 1·076 | 2·153 |
| Converting ... ... ... | 0·353 | 0·705 |
| | 3·292 | 6·584 |
| Casting ... ... ... ... | 0·178 | 0·356 |
| Refining ... ... ... | 0·500 | 1·000 |
| Melting ... ... ... | 0·200 | 0·400 |
| Total cost ... ... | 4·170 | 8·340 |

The Butte sulphide-ores are concentrated at the Anaconda works in plants similar to those of Lake Superior. In some of the works, jigs and frue-vanners are used. The concentrates, which contain about 40 per cent. of sulphur, are roasted in

TABLE XV.—COPPER-PRODUCTION IN MONTANA, U.S.A., FOR 1898 AND 1899.*

| Names of Mines and Works. | 1898. | 1899. |
|---|---|---|
| | Tons.† | Tons.† |
| Anaconda ... ... ... ... | 47,863 | 48,176 |
| Boston and Montana ... ... ... | 27,678 | 35,267 |
| Butte and Boston ... ... ... | 3,125 | |
| Butte Reduction-works ... ... | 4,323 | 4,486 |
| Colorado Smelting and Refining Company ... ... ... .. | 3,418 | 4,273 |
| Hecla Consolidated Mining Company | 53 | 69 |
| Parrot Company ... ... ... | 5,555 | 4,743 |
| Montana Ore-purchasing Company... | 5,841 | 6,857 |
| Other Mines and Works ... ... | — | 2,578 |
| Totals ... | 97,856 | 106,449 |

* Compiled from *The Mineral Industry*. † Tons of 2,240 pounds.

mechanical furnaces down to about 6 per cent. Ores containing 10 to 12 per cent. of sulphur are not roasted. The coarse ore is smelted in cupola-furnaces, and the fine ores in reverberatory furnaces.

* Third edition, 1900, page 100.

### (3) *Michigan, U.S.A.*

*Lake Superior District.*—The copper is found in this region in the metallic state in the upturned rocks of Algonkian age, known as the Keweenawan series, in both the sedimentary and the interstratified igneous rocks, which were deposited unconformably on the iron-bearing Huronian series, and they in turn are overlapped by nearly horizontal Cambrian sandstones.

The Keweenawan series consist of eruptive layers and of sandstones and conglomerates largely made up of a detrital eruptive material, the latter predominating. These rocks have experienced intense and long-continued metamorphic action, which has produced amygdaloidal structure. The metal occurs as a cement, binding together and replacing the pebbles of a porphyry-conglomerate; or filling the amygdules in the upper portions of the interbedded sheets of massive rocks; or as irregular masses, sometimes of great size, in veins, or in irregular masses along the contacts between the sedimentary and the igneous rocks. When found in fissure veins, they traverse the beds at right angles to the strike and dip. Minute specks of copper-minerals are found in the succeeding sandstones, but not in sufficient quantity to be of any commercial importance. No precious minerals are found in association with the copper, except silver, which also occurs in the metallic state.* The rocks of the Keweenawan system are most strongly developed on the southern shore of Lake Superior at Keweenaw Point, where they dip north-eastward under Lake Superior, and reappear with a south-easterly dip on Isle Royale and the Canadian shore. Western Lake Superior occupies this synclinal trough.

There are three districts in this locality: (1) Keweenaw Point on the easternmost end; (2) Portage Lake in the middle; and (3) Ontonagon, at the western end.†

The cupriferous strata on the Keweenaw peninsula have sandstone on either side. The underlying sandstone, to the east and south, is generally held to be non-conformable with the traps of the Keweenawan group, and are considered to belong to the Potsdam series. Copper is occasionally found in the eastern sandstone, near the point of contact with the trap, where evidences of

* Iron-ores occur abundantly in the amygdaloids, especially in the epidotes.

† The gaps between these three districts are being rapidly filled by the development of new mines.

igneous influence are plainly discernible, and in Ontonagan county, fine copper has been found in the overlying sandstone-conglomerate in the Porcupine mountains. The western sandstone is superimposed upon the Keweenawan beds and is apparently in place.

The outcrop of the trap-rock formation, between the two sandstones, varies from 2 to 6 miles wide. The outcrop is narrowest where the dip of the strata is greatest, and widest where the strata dip least sharply. Toward the middle of the Keweenaw peninsula the western sandstone is lost under the water, and at Bête Gris Bay, the eastern sandstone also plunges beneath Lake Superior, leaving the traps and conglomerates in sole possession of the tip of the peninsula for the last 10 miles, the waters covering the entire formation at the end of Keweenaw Point.

The Portage Lake district is the most important, and here are located the Calumet and Hecla, Osceola, Peninsula, Quincy, Tamarack, etc., mines. The miners distinguish the native copper in the different workings as occurring either in amygdaloid or conglomerate. At one time, this section was the leading copper-producer in the United States, but of late years, Butte, Montana, has taken the lead. The locality was evidently known to some prehistoric races who mined for the metal, ample evidence of which was found by the early explorers. In the workings, large masses of native copper, weighing many tons, have been encountered, and the amygdules are often entirely filled with native copper; but when their filling is not exclusively metallic, the copper is accompanied by native silver, calcite, quartz, chlorite, prehnite, epidote, etc. When, as sometimes occurs, a mass of copper is met with, extending some 20 or 30 feet along the course of a vein, and weighing considerably above 100 tons, its removal is attended by a certain amount of difficulty. In order to extract such a mass of copper, the rock is first stoped from one side of it, and the metal subsequently divided, by means of cross-cut chisels, into fragments of such dimensions as to admit of its being taken upon rollers to the shaft and thence raised to the surface.

The theory almost universally adopted is that the native copper was deposited by precipitation in the cavities in the strata from the waters of the overlying sea. The traps being dense rocks, usually basic, there was little opportunity for the deposition of copper therein. The amygdaloids contained an infinite variety

of granular and crystalline rock-forms, the calcareous and siliceous portions of which were dissolved quite readily by the waters, presumably powerfully impregnated with salts and minerals, and in the apertures left by the dissolution of the chalky and siliceous nodules the native copper was deposited, when precipitated from the overlying waters.

A cross section of the trap formation, at any given point, shows a large number of beds of trap, amygdaloid and conglomerate rocks, lying one upon the other. These vary greatly in thickness, but are persistent, both as to length and depth. Geological observation in the copper-district has been founded very largely on the conglomerates as base-lines, and many conglomerate-reefs have been identified and traced for considerable distances. Of the conglomerates, many carry copper in minute quantities, but only two have been mined, these being the Calumet and Allouez conglomerate-reefs. The former is now being mined on by the Calumet and Hecla, the Tamarack, and the Tamarack Junior mine of the Osceola Consolidated Company. The Allouez conglomerate has been worked by the Allouez and Peninsula mines.

Nearly all of the amygdaloids carry copper to some extent, but not all of them in sufficient quantity to render mining profitable. With the exception of the mines just noted as working the conglomerates, all the active mines of the district, including producers and properties in process of development, are working on amygdaloid lodes, none of which approach the Calumet conglomerates in their copper-contents. The dip of the various strata, copper-bearing or otherwise, varies greatly at different points, ranging from 73 degrees with the horizon to as flat as 25 degrees.

In addition to the copper-bearing amygdaloids and conglomerates, there are three other sources of copper-supply in the district: (1) Fissure veins, which cross the formation at right angles, and are nearly vertical in dip; (2) contact veins, and (3) ores. Some of the mines, when first opened, contained in the surface workings large quantities of black oxide of copper and green carbonates, formed by the action of the elements from the native copper which replaced it at a little depth. Some fissure veins of sulphide of copper were found, which in some instances are associated with arsenide of copper.

The permanency of the ore-deposits in these regions requires no further evidence than the depth of some of the shafts from whence the ores are raised. These in several instances exceed 4,000 feet, and shafts are being continued to a depth of more than 5,000 feet. When it is considered that the productive Lake Superior mines extend along a narrow belt nearly 100 miles in length, it is evident that they will constitute, for a long time to come, important factors in the world's copper-supply.

Lake Superior copper has always been sold on the market as refined copper, but as the largest portion of the copper from other districts is now electrolytically refined, Lake Superior brands no longer enjoy the same exclusive reputation. The deterioration of Lake Superior copper is attributed to closer concentration, which furnishes a less pure concentrate for smelting, and it is also possibly due to the presence of minute quantities of iron in the copper.

In the Lake Superior district, the ores are on an average of a low grade, the copper being disseminated through the rock in small metallic particles. This necessitates a preliminary stamping of the rock and the subsequent concentration of the mineral, which is sent to the smelter. Large ball-stamps are employed at the reduction-works capable of crushing 300 to 550 tons per stamp per day of 20 hours, and the stamped product is concentrated on jigs and slime-tables. Owing to the low grade of the rock, every possible economy has to be used in mining, with great capacity of the crushing-plants and all the accessory operations, so as to reduce costs to a minimum. The cupriferous rocks of this region do not carry any gold.

The stamps discharge the ore through screens, with perforations varying from $\frac{3}{16}$ to $\frac{3}{8}$ inch in diameter, to hydraulic separators, and thence to jigs and rotary slime-tables. The only middlings produced are in re-jigging the overflow from the coarse jigs, which make the richest concentrates. The middling heads that are thus separated by re-jigging from the waste-tailings are sent back to the stamps for re-crushing. At the mills, two grades of concentrated products are made, carrying about 25 per cent. and 85 per cent. of metallic copper respectively.

To give an idea of the magnitude of the operations at these mines, an outline will be given of the Calumet and Hecla mills and smelters. The stamp-mills are located at Lake Linden, 4

miles from the mine, and have a combined daily capacity of about 10,000 tons. Lately, Wilfley tables have been introduced and are found valuable in saving the extra fine particles of metal, which the slime tables have lost. The water for washing the rock is furnished by large pumping-engines, one of which has a capacity of 65,000,000 gallons daily, and the auxiliary pumps have a capacity of 30,000,000 gallons daily. The daily disposition of upwards of 8,000 tons of stamp-sands is a heavy problem. The shores of the lake were filled with stamp-sands in a few years, after the mills started, and it then became necessary to elevate the sludge of sand and water by a "sand-wheel." This wheel is fitted on its inner

TABLE XVI.—COPPER-PRODUCTION IN MICHIGAN, U.S.A., FROM 1896 TO 1899.

| Names of Mines. | 1896. | 1897. | 1898. | 1899. |
|---|---|---|---|---|
| | Tons.* | Tons.* | Tons.* | Tons.* |
| Arcadian ... ... ... ... | 223 | — | — | 890 |
| Arnold ... ... ... ... | 341 | 68 | — | — |
| Atlantic ... ... ... .. | 2,088 | 1,963 | 1,950 | 2,087 |
| Baltic ... ... .. | 277 | 19 | 18 | 269 |
| Calumet and Hecla ... .. ... | 40,004 | 38,583 | 42,010 | 43,750 |
| Centennial ... .. .. .. | 326 | 300 | — | — |
| Central ... ... . ... | -- | 139 | 130 | -- |
| Franklin ... ... ... ... | 553 | 1,171 | 1,593 | 504 |
| Mass ... ... ... | 19 | — | — | 27 |
| Osceola ... ... ... ... | 5,071 | 5,661 | 5,269 | 4,888 |
| Quincy Mining Company ... ... | 6,384 | 7,301 | 7,309 | 6,384 |
| Tamarack ... ... ... ... | 8,288 | 8,777 | 10,044 | 7,924 |
| Wolverine ... ... ... ... | 2,009 | 2,048 | 2,159 | 2,137 |
| All other mines ... ... ... | 22 | 33 | 11 | 662 |
| Totals ... ... | 65,605 | 66,063 | 70,493 | 69,522 |

* Tons of 2,240 pounds.

perimeter with wooden buckets, which take the sludge from the pit, in which it is deposited by the launders from the mill, and elevate the sand in solution to a launder on high trestles, by which the sand and water are carried far out into the lake. There are four sand-wheels, two of 40 feet and two of 50 feet diameter, with a combined daily capacity of 8,200 tons of sand and 100,000,000 gallons of water. Another sand-wheel has been erected, 60 feet in diameter. The company smelts its own copper at the smelters, one of which is erected at South Lake Linden, where the low-grade mineral is treated, thus saving transportation charges on a considerable amount of worthless gangue contained in the low-grade stuff. The other smelter is situated at Black

Rock, Buffalo, on the banks of the Niagara river, and is very complete. An electrolytic-plant has also been erected there, for the reduction of mineral carrying considerable values in silver.

To give an idea how close is the margin at which some of these mines have to work, it is only necessary to adduce the example of the Atlantic mine. That mine in 1894 crushed 330,000 tons of ore, producing 3,120 tons of mineral or concentrate, less than 1 per cent. of the quantity of rock stamped, yielding 2,416 tons of copper or 77½ per cent. of copper in the concentrates, and the copper was sold at 5·25d. (10½ cents) per pound.

TABLE XVII.—COPPER-PRODUCTION OF THE LAKE SUPERIOR DISTRICT FROM 1855 TO 1900.

| Years. | Tons.* | Years. | Tons.* | Years. | Tons.* |
|---|---|---|---|---|---|
| 1855 | 2,593 | 1871 | 11,493 | 1887 | 33,941 |
| 1856 | 3,667 | 1872 | 10,961 | 1888 | 38,600 |
| 1857 | 4,254 | 1873 | 13,527 | 1889 | 39,363 |
| 1858 | 4,089 | 1874 | 15,328 | 1890 | 45,272 |
| 1859 | 3,990 | 1875 | 16,089 | 1891 | 50.992 |
| 1860 | 6,727 | 1876 | 17,089 | 1892 | 55,445 |
| 1861 | 6,778 | 1877 | 17,422 | 1893 | 50,270 |
| 1862 | 6,056 | 1878 | 18,610 | 1894 | 51,035 |
| 1863 | 5,797 | 1879 | 19,049 | 1895 | 57,737 |
| 1864 | 5,576 | 1880 | 22,195 | 1896 | 63,419 |
| 1865 | 6,409 | 1881 | 22,440 | 1897 | 63,707 |
| 1866 | 6,138 | 1882 | 25,516 | 1898 | 66,056 |
| 1867 | 7,819 | 1883 | 26,652 | 1899 | 65,602 |
| 1868 | 9,345 | 1884 | 30,961 | 1900 | 64,800 |
| 1869 | 11,886 | 1885 | 32,209 | | |
| 1870 | 10,992 | 1886 | 36,124 | Total | 1,184,020 |

* Tons of 2,240 pounds.

Table XVII. shews that the increase in the production of copper in the Lake Superior district has not been as great as one would surmise, considering the extent of the deposits, but it ought to attain 10 years hence, 100,000 tons. It takes considerable time in those regions to open new mines and to develop them into a producing condition.

### (4) *Copper-production of the United States.*

Tables XVIII. and XIX. give detailed figures of the production from the various States.

Table XX. exhibits the increased consumption of copper in the United States. The consumption of copper in the United States for 1899 amounted to 174,822 tons. About two-thirds of the copper produced in the United States is electrolytically refined.

TABLE XVIII.—PRODUCTION OF COPPER IN THE UNITED STATES FROM 1897 TO 1900 INCLUSIVE.

| States and Territories. | 1897. | 1898. | 1899. | 1900. |
|---|---|---|---|---|
| | Tons.* | Tons.* | Tons.* | Tons.* |
| Arizona ... ... ... ... | 36,170 | 49,475 | 55,972 | 49,700 |
| California ... ... ... ... | 6,308 | 9,618 | 10,677 | — |
| Colorado ... ... ... ... | 4,213 | 4,853 | 4,739 | — |
| Michigan ... ... ... ... | 65,107 | 69,951 | 69,574 | 64,800 |
| Montana ... ... ... ... | 105,874 | 96,866 | 106,229 | 113,800 |
| Utah ... ... ... ... | 1,721 | 2,404 | 4,156 | — |
| Eastern and Southern States ... | 1,664 | 1,999 | 1,698 | — |
| All others ... ... ... ... | 901 | 953 | 2,227 | 40,800 |
| Copper in sulphate of copper ... | 1,867 | 3,132 | 4,245 | 9,370 |
| Totals ... ... | 223,825 | 239,251 | 259,517 | 278,470 |

* Tons of 2,240 pounds.

TABLE XIX.—PRODUCTION OF COPPER IN THE UNITED STATES.*

| Year. | Arizona. | California. | Colorado. | Michigan. | Montana. | New Mexico. | Utah. | Eastern & Southern States. | All others not enumerated. |
|---|---|---|---|---|---|---|---|---|---|
| | Tons.† | Tons.† | Tons.† | Tons.† | Tons.† | Tons.† | Tons.† | Tons.† | Tons.† |
| 1880 | 616 | ? | ? | ? | ? | ? | ? | ? | ? |
| 1881 | 1,726 | ? | ? | ? | ? | ? | ? | ? | ? |
| 1882 | 8,028 | 369 | 667 | 25,505 | 4,043 | 388 | 270 | 873 | 388 |
| 1883 | 10,659 | 715 | 515 | 26,454 | 11,010 | 368 | 153 | 449 | 1,053 |
| 1884 | 11,934 | 391 | 899 | 20,950 | 19,238 | 27 | 118 | 545 | 594 |
| 1885 | 10,137 | 209 | 512 | 32,482 | 30,266 | 36 | 57 | 113 | 513 |
| 1886 | 7,141 | 192 | 182 | 35,830 | 25,718 | 248 | 223 | 154 | 594 |
| 1887 | 7,941 | 714 | 898 | 33,836 | 35,134 | 126 | 1,116 | 90 | 1,086 |
| 1888 | 14,821 | 700 | 724 | 38,617 | 43,977 | 728 | 952 | 45 | 1,445 |
| 1889 | 14,702 | 759 | 1,384 | 39,024 | 46,691 | 1,645 | 1,072 | 40 | 1,618 |
| 1890 | 16,508 | 714 | 2,678 | 44,953 | 49,553 | 388 | 273 | 1,875 | ? |
| 1891 | 18,700 | 1,673 | 3,125 | 51,071 | 50,536 | 714 | 759 | 580 | 1,540 |
| 1892 | 17,135 | 1,430 | 3,236 | 47,960 | 73,348 | 223 | 893 | 580 | 536 |
| 1893 | 19,550 | 1,261 | 3,179 | 50,653 | 69,066 | 123 | 585 | 185 | 1,502 |
| 1894 | 19,880 | 54 | 2,914 | 51,128 | 81,793 | ? | 528 | 1,088 | 483 |
| 1895 | 21,575 | 101 | 2,734 | 57,920 | 86,950 | ? | 1,190 | 1,453 | 601 |
| 1896 | 32,922 | 880 | 4,259 | 64,312 | 102,213 | ? | 1,585 | 1,674 | 915 |
| 1897 | 36,170 | 6,308 | 4,213 | 65,107 | 105,874 | ? | 1,721 | 1,664 | 901 |
| 1898 | 49,475 | 9,618 | 4,853 | 69,951 | 96,866 | ? | 2,404 | 1,999 | 953 |
| 1899 | 55,972 | 10,677 | 4,739 | 69,574 | 106,229 | ? | 4,156 | 1,698 | 2,227 |
| 1900 | 49,700 | ? | ? | 64,800 | 113,800 | ? | ? | ? | 40,800 |

* Compiled from *The Mineral Industry*. † Tons of 2,240 pounds.

## (5) *Mexico.*

*Boleo Mine in Lower California.*—At Boleo, opposite Guaymas, on the peninsula of Lower California, is located this now wellknown copper-mine, and Mr. E. Fuchs has given the following description in his "Notes sur les Gisements de Cuivre de Boleo,"* of this remarkable deposit of copper-ore, which occurs

* *Association Française pour l'Avancement des Sciences*, 1885.

in Tertiary sandstones, conglomerates and tufas. The eastern slope of the (mostly eruptive) mountain-range extending through the peninsula is a plateau, gently descending towards the Gulf of California, and cut by precipitous cañons. It is formed of strata containing characteristic Miocene fossils. Tufas decidedly predominate, and the series contains three or four copper-bearing beds, covering a large area, and cropping out at many places in the cañons. These lie immediately upon conglomerates formed of pebbles of eruptive rock (different and characteristic for each horizon) and are overlain by clayey tufas. The whole is traversed by several fissures, of which the largest and most important is a fault-fissure, occurring at the western border of the district and striking about parallel with the sea-shore.

TABLE XX.—PRODUCTION AND CONSUMPTION, AND IMPORTS AND EXPORTS OF COPPER IN THE UNITED STATES SINCE 1882.

| Years. | Imports. | Exports. | Stock on hand on January 1st. | Production. | Consumption |
|---|---|---|---|---|---|
| | Tons.* | Tons.* | Tons.* | Tons.* | Tons.* |
| 1882 | 237 | 2,788 | ? | 41,191 | ? |
| 1883 | 282 | 22,630 | ? | 52,101 | 16,359 |
| 1884 | 86 | 47,245 | 13,394 | 66,138 | 18,979 |
| 1885 | 256 | 50,966 | 13,394 | 75,934 | 22,993 |
| 1886 | 238 | 29,605 | 15,625 | 72,428 | 40,918 |
| 1887 | 94 | 19,196 | 17,857 | 82,700 | 63,598 |
| 1888 | 48 | 35,714 | 17,857 | 104,338 | 53,047 |
| 1889 | 55 | 32,589 | 33,482 | 109,253 | 81,184 |
| 1890 | 296 | 17,857 | 29,018 | 119,609 | 85,977 |
| 1891 | 1,408 | 51,394 | 45,089 | 133,511 | 94,685 |
| 1892 | 693 | 40,198 | 33,929 | 148,774 | 118,201 |
| 1893 | 2,472 | 80,387 | 25,000 | 149,544 | 70,629 |
| 1894 | 5,235 | 75,737 | 26,073 | 163,394 | 84,267 |
| 1895 | 7,194 | 54,332 | 34,698 | 177,881 | 125,619 |
| 1896 | 12,234 | 125,851 | 38,822 | 214,149 | 102,083 |
| 1897 | 12,026 | 128,851 | 21,821 | 227,763 | 126,438 |
| 1898 | 19,410 | 133,824 | 24,269 | 239,241 | 122,382 |
| 1899 | 42,218 | 111,573 | 39,608 | 259,517 | 174,822 |

* Tons of 2,240 pounds.

In the ore-beds above the ground water-level, disseminated oxidized ores prevail, such as black oxide of copper, and the protoxide, with atacamite ($CuCl_2 + 3CuO + 3H_2O$), azurite, malachite and chrysocolla, with crednerite ($2Mn_2O_3, 3CuO$). In the second ore-bed (counting downward) there are peculiar globular concretions, like oolites, of copper oxide and carbonate, sometimes several inches in diameter, which are locally called *boleos,* whence the name of the district. The third ore-bed lies

in part below the ground water-level, and contains, in addition to the foregoing minerals, copper sulphides—chalcosine ($Cu_2S$) and covelline ($CuS$). The ore-beds are composed of tufa, in which ores in disseminated spots and veinlets, as well as globular concretions, are irregularly distributed, with a visible tendency to concentrate towards the bottom of the bed, where they form a compact ore-layer, 6 to 10 inches thick.

The Boleo mine produces about 10,000 tons of copper per annum. The black copper resulting from smelting is shipped to the United States.

*Michoacan.*—At Inguaran, in the Ario district in the State of Michoacan, are large bodies of low-grade concentrating ores, and these mines have passed into the hands of Messrs. de Rothschild, who will build a line of railway from the mines to Zihuatanejo on the Pacific. In ore-samples which the writer has seen, the copper sulphides seem to be pretty evenly disseminated in a granitic rock and should form an ideal concentrating material.

*Sonora.*—During a recent journey into some portions of the State of Sonora, the writer had occasion to inspect some promising copper-deposits and there is very little doubt that Mexico will, in course of time, become an important producer of copper.

The copper-mining industry in Mexico is greatly benefited by Messrs. Guggenheim Brothers, who own large smelting works at Aguas Calientes, and ore from smaller properties is sent to these works for treatment.

### (6) *Canada and British Columbia.*

*British Columbia.*—The principal ore-deposits are located near Rossland, and Mr. R. G. McConnel, of the Geological Survey of Canada, after a short visit in 1894, reported* the country about Rossland to be "an area of eruptive rock, mostly diorite and uralite-porphyrite, cut by many dykes," but as no complete geological survey had been made, nor any lithological study, only a very general description has been given. The main mass of all the country is evidently diorite, although it presents many differ-

* *Summary Reports of the Geological Survey of Canada*, 1894-5, page .

ent gradations in composition and structure, varying from a fine grained aphanitic rock with very little hornblende at one extreme to nearly massive hornblende at the other, often showing mica and pyroxene. Much of it looks like a basic syenite, and the ore-bodies traverse the diorite. In going over this region, the variations are seen to be very marked, in some places the rock being stratified as if of sedimentary origin, but in all probability it is a more or less altered eruptive. Porphyry dykes from 1 foot up to 60 and 80 feet wide traverse the country, many with a north-and-south strike, but with no apparent dislocation of the veins through which they cut; indeed, at six such points of intersection the ore seemed to be concentrated, and even to follow along the dyke for some distance, but this must be made clear by further underground work.

In the Rossland district, prospecting work has shown clearly that there is a large system of lines of fracture with an east-by-west and north-east by south-westerly trend, and a persistent northerly dip, along which more or less ore has concentrated, either as bodies of solid sulphides or sulphides scattered through the country-rock. Some of these fissures can apparently be traced through several 1,500 feet claims, and along them are the large ore-shoots now being mined or developed, the maximum width of pay-ore so far being about 35 feet. Many of these fissures have been or are now being prospected, and in many instances with surface-indications of the most unfavourable character, the improvement has been very marked in the increase of the amount of ore and its value. The great probability that more rich ore-shoots will be found by following these fissures has made all such property valuable, and is deciding the commencement of extensive exploratory work. Again, large shoots of low-grade ore, mostly of coarse grained magnetic-iron pyrites or pyrrhotite, assaying from traces to £1 5s. to £1 10s. (6 to 8 dollars) in gold, have been found, and are being explored for high-grade ore, and so far with some success.

The surface of these ore-shoots is covered with the typical iron capping, or reddish brown sintery mass, and experience enables the prospector to distinguish between disintegrating sulphides and barren diorite, heavily iron-stained by the oxidizing of the bisilicates, or the iron-pyrites nearly always present in this rock. Although it is difficult to prospect such rock, which

may be much iron stained but indicates no vein whatever in the vicinity, nearly all work is done along one wall, and the ore appears to follow along one wall, where the rock is not too full of fissures that disguise the true conditions. It is doubtful, however, if more than one wall really exists, although a parallelism of lines of fracture may for a short distance seem to prove the contrary. Wherever the ore is found to consist almost of pure sulphides, it will be found lying along and parallel to such a wall, after which ore is disseminated more or less throughout the enclosing rock, often following along small fissures, which in some cases form small veins of good ore that run for a considerable distance away from the main deposit. In all the mines, the ground is faulted, thus dislocating the ore-deposits and stringers, and complicating the search.

Copper-ores also occur at Nelson, in the Boundary District, around the Kootenay Lake, on Coal Hill, in Copper Creek, near Pitt Lake, on Vancouver Island, and elsewhere.

The ores nearly all carry gold and silver, but the average copper-contents are low, and in the Le Roi mine do not exceed 2½ per cent., but the gold-value is about £2 to £2 10s. (10 to 12 dollars) and silver 1½ ounces per ton. Other mines are the War Eagle, Centre Star, Iron Mask, Josie; and in the Nelson District, the Silver King is the leading producer.

*Canada.*—The chief centre of production is Sudbury, where the ores also carry nickel, and are worked for both copper and nickel. They contain about 3 per cent. of copper and 2½ per cent. of nickel. The ore-bodies occur in igneous rocks as irregular masses, and consist of an aggregate of pyrrhotite and chalcopyrite with various nickel-minerals.

### (7) *Chile.*

Chile at one time was the greatest copper-producer in the world, whereas now it takes the fourth place on the list. Its total production for 1899 amounted to 25,000 tons from the working of a great number of small mines, no less than 3,500 sending their ores to Valparaiso, Lota, Coronel, Coquimbo, Chañaral, Guyacan, Tocopilla and other works, where they are smelted and whence the product is shipped to Europe.

The principal copper-mines are situated in the provinces of

Atacama, Antofagasta, Coquimbo and Aconcagua, and the most important mines are those of San Juan and Carrizal, near Copiapo, la Higuera near Coquimbo, and Tamayo about 65 miles from Coquimbo, situated in a mountain-district.

It is almost impossible to give a general idea of the geological conditions under which the various ore-bodies occur, but in Chile, as in most copper-producing countries, the ores are carbonates to a depth of about 150 feet, followed by 60 feet or more of oxides, and eventually by copper and iron-pyrites.

In the Cordillera district, operations are being facilitated by the construction of railways, and owing to improved prices for copper no doubt Chile will be able to maintain for many years to come its present ratio of production, but it is doubtful whether it will ever reach the old figures, as its exportation in 1882 amounted to about 43,000 tons.

Some of the mines have reached depths of 1,700 to 1,800 feet, which proves that the ore-bodies in that country are of a permanent character. The largest proportion of the ore is smelted in reverberatory furnaces. No doubt Chile has felt the exhaustion of the rich surface-ores, and whatever copper is now produced in those regions comes from the poorer sulphide-zones.

### (8) *Germany.*

*Mansfeld.*—At Mansfeld, in the Southern Harz mountains, copper-ores occur, disseminated through sedimentary beds, in which they have been chemically deposited, locally termed *kupferschiefer*, or copper-bearing shale, and in these shales mining has been extensively carried on for centuries. The metalliferous bed occurs in the Zechstein, a member of the Permian formation, which is regarded as the equivalent of the Magnesian Limestone of England. At Mansfeld, the highest horizon of the series consists largely of unstratified gypsum, in which are numerous cavities, locally called *gypsschlotten*, caused by the solvent action of water upon sulphate of lime. With the gypsum is associated a soft bituminous dolomitic limestone, locally known as *asche*, and beneath this follows a stratified fetid limestone, below which is the true Zechstein, giving name to the formation. In depth, this passes into a bituminous marly shale, the lowest portion of which, seldom above 18 inches in thickness, constitutes the chief copper-bearing stratum, and extends

with wonderful regularity for many miles. Of this, sometimes only from 4 to 5 inches is sufficiently rich to pay the cost of smelting, the proportion of copper in the ores treated varying from 2 to 5 per cent. Under the cupriferous shale, is a calcareous sandstone, varying in colour from white to grey, which is in part a conglomerate. This, in accordance with its colour, is called either the white layer, *weissliegendes*, or grey layer, *grauliegendes*, and sometimes contains copper-ores. The area over which these copper-bearing shales are found has an extent of about 190 square miles.

In the slates the ores are sulphides, but in the underlying sandstones carbonates predominate, evidently due to the decomposition of the kupferschiefer ores, and their infiltration into the sandstone. Formerly only the shaly ores were treated, but now the underlying siliceous sandstone-deposits are utilized not only for copper, but for their cobalt and nickel-contents. In some localities, the ore is for the most part an argentiferous *fahlerz*, and a considerable quantity of silver is obtained in these districts.

The production of copper in 1898 of the Mansfeld mines amounted to about 18,000 tons.

*Rammelsberg.*—After Mansfeld, the most important copper-mine in Germany is the Rammelsberg deposit, which occurs as a big lenticular mass in Devonian slates.

### (9) *Spain and Portugal.*

In the south-western portion of the Sierra Morena is a zone of clay-slate, some 120 miles in length, which courses in a north-westerly direction through the province of Huelva, from Aznalcollar and Castillo de las Guardas, in Spain, to San Domingos in Portugal.

The age of the enclosing rocks remains doubtful, as some geologists believe them to be Silurian, and others Devonian. As a rule they are vertical, or nearly so. They enclose enormous deposits of cupriferous iron-pyrites, and their occurrence throughout this whole belt is so very uniform that the description of one mine is the history of all of them. Near the ore-deposits, and parallel to them, are dykes of porphyry, syenite and diabase. The deposits of cupriferous pyrites consist of a series of more or less

continuous lenticular masses, which occur generally at the junction of rocks of dissimilar character and consequently form contact-deposits. They extend for a great length and range from all sizes up to about ¾ mile in length, and reach a width of 500 feet. The ore is an intimate mixture of iron-pyrites with a little copper-pyrites.

At Rio Tinto, there are four lodes, the north, middle, south and valley. The slate, which stands nearly vertical, is altered in the immediate vicinity of the deposits by the action of the iron-salts resulting from the decomposition of pyrites, and not only becomes softer but also assumes a yellowish-white or reddish-grey tint. Although some rich ore is met with in patches, the deposit is of low grade, averaging between 3 and 4 per cent. The length of this deposit is over 2,000 feet, and a depth of over 1,000 feet has been reached in the workings. It was wrought by the Romans, and some of their old workings reached a depth of 300 feet. The Tharsis workings are west of Rio Tinto, and the deposits resemble those of the last-named locality as to their mode of occurrence.

In addition to copper, the Rio Tinto and Tharsis pyrites contains about 1½ ounces of silver per ton, together with traces of gold, which for many years were not recovered; but, after the introduction of the Claudet process, the precious metals were also obtained.

In 1898, the Rio Tinto mines produced 1,465,380 tons of ore, of which 820,862 were reserved for local treatment, the remainder being ore for shipment.* The amount of copper produced at the mines was 20,426 tons; the copper in the pyrites shipped was 13,456 tons, making a total of 33,882 tons.

The average copper-content of the ore is 2·85 per cent. The reserve-heaps, from which the copper is extracted at a very low cost, are estimated to contain 114,700 tons of fine copper. The shipping ores are an important source of revenue, as besides the copper, the sulphur is made available in the production of sulphuric acid, and is being paid for at the rate of about 5d. a unit, which on 48 per cent. of sulphur, amounts to £1 per ton. By the aid of the diamond drill, the ore-reserves have been estimated at over 130,000,000 tons, and with the present annual output of 1,400,000 tons there are still 70 years of production in sight at this mine.

* *The Mineral Industry*, vol. vii., page 217.

The Tharsis mines comprise six lodes or deposits of the same general character as the Rio Tinto, and the workings are of great antiquity. The ore is piled in heaps, where it undergoes natural oxidation, expedited by intermittent washings with water. The copper is precipitated from the leach-water on iron in creosoted timber-sluices. A large quantity of the pyrites is exported.

The Mason and Barry Company has mines in Portugal, and the character of the ore and the percentage of copper are about the same as at Rio Tinto. The copper-bearing formation of Spain extends into Portugal and the three most important deposits are those of San Domingos, Aljustrel and Grandola.

TABLE XXI.—PYRITES AND COPPER STATISTICS FROM THE REPORTS OF THE RIO TINTO COMPANY.

| Years. | Pyrites Extracted. | | | | Pyrites Consumed. | | Copper produced at Mines. |
|---|---|---|---|---|---|---|---|
| | For Shipment. | For Local Treatment. | Totals. | Average Copper-contents. | Weight. | Average Copper-contents. | |
| | Tons. | Tons. | Tons. | Per cent. | Tons. | Per cent. | Tons. |
| 1876 | 189,962 | 159,196 | 349,158 | 1·500 | 158,597 | 1·500 | 946 |
| 1877 | 251,360 | 520,391 | 771,751 | 2·375 | 211,487 | 2·000 | 2,495 |
| 1878 | 218,818 | 652,289 | 871,107 | 2·780 | 211,403 | 2·180 | 4,184 |
| 1879 | 243,241 | 663,359 | 906,600 | 2·780 | 236,849 | 2·450 | 7,179 |
| 1880 | 277,590 | 637,567 | 915,157 | 2·865 | 274,210 | 2·481 | 8,559 |
| 1881 | 249,098 | 743,949 | 993,047 | 2·750 | 256,827 | 2·347 | 9,466 |
| 1882 | 259,924 | 688,307 | 948,231 | 2·805 | 272,826 | 2·401 | 9,740 |
| 1883 | 313,291 | 786,682 | 1,099,973 | 2·956 | 288,104 | 2·387 | 12,295 |
| 1884 | 312,028 | 1,057,890 | 1,369,918 | 3·234 | 314,751 | 2·241 | 12,668 |
| 1885 | 406,772 | 944,694 | 1,351,466 | 3·102 | 354,501 | 2·270 | 14,593 |
| 1886 | 336,548 | 1,041,833 | 1,378,381 | 3·046 | 347,024 | 2·306 | 15,863 |
| 1887 | 362,796 | 819,642 | 1,182,438 | 3·047 | 385,842 | 2·283 | 17,813 |
| 1888 | 434,316 | 969,317 | 1,403,633 | 2·949 | 393,149 | 2·208 | 18,522 |
| 1889 | 389,943 | 824,380 | 1,214,323 | 2·854 | 395,081 | 2·595 | 18,708 |
| 1890 | 396,349 | 865,405 | 1,261,754 | 2·883 | 397,875 | 2·595 | 19,183 |
| 1891 | 464,027 | 972,060 | 1,436,087 | 2·649 | 434,532 | 2·651<br>1·309 | 21,227 |
| 1892 | 406,912 | 995,151 | 1,402,063 | 2·819 | 435,758 | 2·569<br>1·465 | 20,017 |
| 1893 | 477,656 | 854,346 | 1,332,002 | 2·996 | 469,339 | 2·659<br>1·544 | 20,887 |
| 1894 | 498,540 | 888,555 | 1,387,095 | 3·027 | 485,441 | 2·594<br>0·988 | 20,606 |
| 1895 | 525,195 | 847,181 | 1,372,376 | 2·821 | 518,560 | 2·595<br>0·986 | 20,762 |
| 1896 | 591,752 | 845,580 | 1,437,332 | 2·931 | 549,585 | 2·529<br>1·068 | 20,817 |
| 1897 | 575,733 | 812,293 | 1,388,026 | 2·810 | 582,540 | 2·595<br>0·967 | 20,826 |
| 1898 | 644,518 | 820,862 | 1,465,380 | 2·852 | 618,110 | 2·600<br>1·023 | 20,426 |
| 1899 | 644,271 | 1,005,573 | 1,649,844 | 2·719 | 636,323 | 2·511<br>1·120 | 20,230 |
| 1900 | 704,803 | 1,189,701 | 1,894,504 | 2·744 | 665,967 | 2·553<br>1·187 | 21,120 |

### (10) *Australasia.*

*South Australia.*—Copper is known to exist throughout the Commonwealth, and at one time was extensively mined in South Australia, which still glories in the wonderful tales of its past copper-production. The Kapunda mine, opened up in 1842, and the oldest copper-mine in South Australia, was closed in 1879. In 1845, the Burra Burra mine was discovered, but it is exhausted.

The Wallaroo and Moonta mines were discovered in 1860 and 1861, and are at present the chief copper-producers in South Australia. The Wallaroo mine is situated on Yorke Peninsula, 10 miles north of the Moonta mines. The country-rock is schistose. The average grade of the ore in 1897 was 15·9 per cent., and the quantity of copper produced was 5,073 tons. The Moonta mine is also situated on the Yorke Peninsula. The deepest shaft is down 2,400 feet. The cost of producing copper is £48 per ton.

*New South Wales.*—This colony is spoken of as a great copper-producer, although there is only one large ore-deposit, which furnishes the bulk of the supply, and this is the Great Cobar mine. From the date of the commencement of operations in 1876 to 1892, there were treated from this mine 213,182 tons of ore, giving a return of 23,611 tons of refined metal—an average production of 11·07 per cent. of copper per ton of ore. After lying idle for some time, the mine was let on a 10 years' lease to tributers on a 10 per cent. royalty, with the result that there are now five water-jacket cupola-furnaces in operation, smelting 500 to 600 tons of ore daily, the tributers having wisely discarded the old reverberatory-smelting methods.

*Queensland.*—Cupriferous deposits abound in Queensland; Peak Downs and Mount Perry acquired great celebrity, but were ultimately abandoned. In Northern Queensland, copper is found throughout the Cloncurry district, in the upper basin of the Star River, and the Herberton district. The returns from the copper-fields in this colony are at present small, owing to the lack of suitable fuel for smelting purposes, which renders the economic treatment of the ore difficult; and the development of the mines is greatly retarded by the want of easy and cheaper

communication with the coast; but it is expected that these disabilities will be overcome at no distant date, and a revival of the industry is hoped for. In this connection, should be mentioned the Chillagoe copper-mines; and a railway, to connect the mines with the sea-coast, will start from Bedford. The ore-deposits occur in limestone, and are said to bear some resemblance to those of Arizona.

*Western Australia.*—Copper-deposits have been worked for some years, rich lodes of the metal having been found in the Northampton, Murchison and Champion Bay districts, and also in the country to the south of these districts on the Irwin river.

*Victoria.*—Copper-mining has not attained any great proportions in Victoria, although deposits have been found in several parts of the state, particularly in the Beechworth district, where they have been traced over an area of some 50 square miles.

Copper is sometimes found in the Australian mines in a virgin state, and beautiful specimens of the pure metal have been exhibited at different times, but it occurs generally in the form of oxidized copper-ores, carbonates, sulphates, phosphates and silicates of copper. Copper sulphides and arsenides of copper are generally found in deep sinking. The metal has also been found associated with tin in the form of stannine.

*Tasmania.*—The Mount Lyell mine and adjacent mines in Tasmania have been recently described by Mr. Herbert J. Daly, in a paper read before the Institution of Mining and Metallurgy.*

(11) *Cape Colony.*

The only productive mines are located in Namaqualand, where operations commenced in 1852, the Cape Copper and Namaqua Copper companies having been successful in opening payable ore-bodies. A narrow-gauge railway, 91 miles long, connects the mines with Port Nolloth, on the sea-coast, 300 miles north of Cape Town.

* *Transactions*, 1900, vol. ix., page 80.

Copper is made at the works of the Cape Copper Company by the direct method of Messrs. James and Nicholls.*

### (12) *Russia.*

Copper is found in the Ural and the Altai Mountains, also in the Caucasus, Finland, and in the Kirghese steppes.

In the district of Nijne-Tagilsk is a copper-bearing metamorphic schist, enclosed in limestone belonging to the Upper Silurian formation, and in these schists occurs the celebrated cupriferous mass of Miednoroudiansk. In 1836, a block of malachite was found in this locality, weighing 330 tons.

The bedded deposits of the western slope of the Ural belong to two different formations, the Permian and the Triassic. The principal centres of production are Bogolovsky and Polfsk, and the Kiadabek mine is the largest producer.†

### (13) *Miscellaneous.*

No details have been published relating to the copper-deposits in Japan.

In Sweden and Norway, the production of copper arises from the operations of the Röros, Sulitelma and Falun mines.

Italian ores are derived from three sources: Monte Catini, Mossetana and Baccheggiano.

The opening up of ore-deposits in the Cerro de Pasco district has placed Peru again on the list of copper-producing countries.

Among small producers are Bolivia, Austria-Hungary, Newfoundland and the United Kingdom.

There are good copper prospects in the Transvaal, in the north-eastern portion of the Murchison range in the vicinity of Palabara, but owing to the lack of railway facilities they are not exploited.

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Mr. BENNETT H. BROUGH (London) considered that the chief lesson to be learned from the statistics given by Mr. Eissler was that attention should be devoted to the abandoned copper-mines of Great Britain. For more than a century, Great Britain occu-

* "The Direct Method considered as the future Metallurgical Treatment of Copper-ores, Argentiferous or otherwise," by Mr. Christopher James, *Transactions of the Institution of Mining and Metallurgy*, 1896, vol. v., page 2.

† *A Treatise on Ore-deposits*, by Mr. J. Arthur Phillips, 1884, pages 398-410.

pied the position of the chief-producer of copper in the world. Some of the Cornish copper-mines were remarkably rich, as were also many of those in Cheshire, in Anglesey, and in Ireland. The rapid decadence of that great British industry was due partly to the fact that in Cornwall the copper-ores had given place to tin in depth, and partly to the fact that the great depths attained and the large quantities of water encountered had rendered competition with the vast American and Spanish deposits impossible. There were, however, large areas of mineral-ground unexplored and many old mines worth reopening, should there be a rise in the price of copper. Owing chiefly to the rapid extension of the applications of electricity in all branches of industry, there had been in recent years a steady increase in the market value of copper from £40 per ton in 1894 to £70 nowadays. Advantage should be taken of the impetus thus given to this important branch of mining. If this were done it would be of great national advantage. The consumption of copper had increased at a remarkable rate, and it was a serious question how the increase was to be met. In most countries the output was stationary or diminishing. The only countries that had of recent years shown a considerably increased copper production were Arizona, Japan, Australasia, Cape Colony and Peru. It was to them that we must look for the new sources of supply such as the Mount Lyell mines in Tasmania, the output of which might be largely increased. Japan, where mines started a thousand years ago were still being worked, was now the third largest producer in the world, and its output was rapidly increasing. Mr. Eissler was scarcely justified in stating that no details had been published relating to the copper-deposits of that country. Descriptions and detailed statistics had been abundantly published in the German technical journals; and he (Mr. Brough) had himself shown lantern-photographs of some of the leading mines, in a lecture delivered before the Society of Arts on February 12th, 1900.* That lecture, which covered the same ground as the author's paper, had escaped the latter's notice. The sources of copper-supply had also recently been reviewed by Dr. F. H. Hatch in the *Engineering Magazine*,† by Mr. Nicol Brown and Mr. C. C. Turnbull in a work entitled

* *Journal*, 1899-1900, vol. xlviii., page 721.

† 1900, vol. xviii., page 896; and vol. xix., page 57.

*A Century of Copper* (London, 1900), and by Mr. T. E. Carne in a report to the Government of New South Wales.

The CHAIRMAN (Mr. H. C. Peake) moved a vote of thanks to Mr. Eissler for his valuable paper. He hoped that some of the members would turn their attention now to the production of copper in this country.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

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## DISCUSSION OF MR. H. FOSTER BAIN'S PAPER ON "AN AMERICAN LONGWALL MINING MACHINE."*

Mr. J. S. DIXON (Bothwell) said that the writer stated "of the two general plans of working coal (longwall and room-and-pillar) the former is, where the conditions will allow of its adoption, incomparably the more economical." In Scotland, this was not found to be the case, for the room-and-stall method was preferred for economy, at any rate where that system was suitable at moderate depths. The ripping or brushing of the roads was saved in one case and had to be paid for in the other. A useful device was described in the paper by which the coal was cut into by the cutting-bar at the starting of the machines at their work. In the case of the disc coal-cutting machines, the miners had to cut a hole for the disc, and this added considerably to the cost of working coal with such machines.

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Mr. H. W. HALBAUM's paper on "An Extension of the Equivalent-orifice Theory" was read as follows:—

* *Trans. Inst. M.E.*, 1900, vol. xix., page 144; and vol. xx., page 509.

# AN EXTENSION OF THE EQUIVALENT-ORIFICE THEORY.

By H. W. HALBAUM.

In a previous paper,* the writer showed that the equivalent-orifice theory was simplified by treating it graphically, and, to some extent, this paper must be read as a continuation. The present object is to extend the theory to the case of the mechanical efficiency of the fan, showing the influence of the equivalent orifice thereon. It is assumed throughout this paper that the fan turns at uniform speed, that it acts upon air of uniform density, and that the orifice of passage for each fan maintains a constant value. As this paper deals with power, and as, in this case, the factors of the bulk of the power are pressure and volume, it will be convenient to remember that all pressures are expressed in pounds per square foot, volumes in cubic feet per minute, and powers, consequently, in units of work, or foot-pounds, per minute.

It may be advisable to state one or two points briefly without discussing them, but the proofs may be found in the writer's previous paper, together with the methods by which the maximum volumes and pressures are found. First, to define the angle $\phi$ which governs the entire problem. If $a$ is the equivalent orifice of the mine, and $o$ the orifice of passage possessed by the fan, then

$$\tan \phi = \frac{a}{o} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The value of $o$ is constant for the same fan; but $a$ may vary between zero and infinity.

If $h$ is the effective depression, or the true ventilating pressure; $h_0$ the useless pressure expended on passing the volume through the fan; and $H$, the initial depression, or the total pressure that the fan can produce at the normal speed; then

* *Trans. Inst. M.E.*, 1900, vol. xx., page 404.

$$H = h + h_0; \quad . \quad . \quad . \quad . \quad (2)$$

$$h = H\cos^2\phi; \quad . \quad . \quad . \quad . \quad (3)$$

$$\text{and } h_0 = H\sin^2\phi. \quad . \quad . \quad . \quad . \quad (4)$$

$H$ is constant under the assumed conditions; whilst $h$ and $h_0$ may possess any value between the limits of $H$ and zero, according to the magnitude of the angle $\phi$.

The maximum volume, $V$, that the fan can pass is that which is yielded when the fan acts in the open air; when $a =$ infinity, $h_0 = H$, and $h =$ zero. Then the volume obtained when the fan acts on any mine, artificial or real, is less than $V$, say $v$, and

$$v = V\sin\phi, \quad . \quad . \quad . \quad . \quad (5)$$

$V$ being constant at the normal speed.

The office of the fan is to do work on the air; and this work is composed of two parts, one useful, the other useless, but unavoidable. The useful power in the air is $p$; and

$$p = vh. \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The useful power in the air attains its maximum, when $h = 2h_0$; or when $o^2 = 2a^2$; or when the angle $\phi$ is about $35\frac{1}{4}$ degrees. This statement, however, is very different from saying that the mechanical efficiency attains its maximum at the same angle.

The useless power in the air is $p_0$, and it consists of the power expended in driving the volume, $v$, through the fan, in contradistinction to the power, $p$, expended in driving the volume, $v$, through the mine. The useless power in the air is therefore

$$p_0 = vh_0. \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The useless power in the air attains its maximum when $h_0 = H$; when $v = V$; or when the angle $\phi$ is 90 degrees. Let us call this maximum $P$; then

$$P = VH; \quad . \quad . \quad . \quad . \quad . \quad (8)$$

and $P$ is a constant under the conditions laid down.

This maximum will be of service in the investigation of the present case, as it gives us a standard to which all the various powers in the air may be referred as simple trigonometrical ratios. However, it may be useful to determine a formula for the mechanical efficiency of the fan. If $e$ is the efficiency, and $R$ the indicated power of the fan-engine, we know that

$$e = \frac{p}{R}. \quad . \quad . \quad . \quad . \quad . \quad (9)$$

There can be no dispute about this formula, as $p$ is the only useful power, and $R$ is the total power expended. Now $p = vh$; and it would seem clear that the indicated power, $R$, is the sum of the total power in the air *plus* the power, $p$, expended on the passive resistances, so called, of the machinery. But the total power in the air, $p + p_0 = vh + vh_0 = v\,(h + h_0) = vH$. If $n$ be the units of power expended on the passive resistances of the machinery, we can write the formula of the efficiency $e$, as follows:—

$$e = \frac{v\,h}{v\,H + n}. \qquad (10)$$

This result seems to be sound, but it is not quite the same as that adopted by Mr. Murgue.*

As the present writer has consistently followed the principles of Mr. Murgue up to the present stage, it is only right to explain his reasons for now differing from that engineer's views. The writer believes that the correct value of the first term is $v\,H$; or the product of the volume, $v$, and the initial depression, $H$. Mr. Murgue claims that the proper quantity is $v\,T$; or the product of the volume and the theoretical depression. But it is evident that, whatever be the true value of the first term in the denominator, it must of necessity be less than the denominator as a whole, as the second term, $n$, can never have a minus value. If Mr. Murgue's position be tested in the light of this consideration, however, it will be found untenable. For in many cases in practice, it will be found that $v\,T$ is greater than the entire indicated power. For example, in the case of the 35 feet fan tested by Mr. Walton Brown at Craghead colliery,† the indicator showed 70 horsepower when the fan ran at 50 revolutions; and an easy calculation will show that the power represented by $v\,T$ in the same experiment is 83 horsepower. Again, in the case of the Schiele fan at Great Western colliery as mentioned in Mr. Walton Brown's paper on "Mechanical Ventilators,"‡ at 171 revolutions, the indicator showed 210 horsepower; while the power represented by $v\,T$ was 305 horsepower; or 45 per cent. greater than the total power in the steam-cylinder. It is therefore impossible to accept $v\,T$ as the value of the first term in the denominator; because it makes one

* *The Theories and Practice of Centrifugal Ventilating Machines*, by Mr. Daniel Murgue, and translated by Mr. A. L. Steavenson, 1883, page 58.

† *Trans. Inst. M.E.*, 1892, vol. ii., page 174.

‡ *Ibid.*, 1899, vol. xvii., page 532.

term greater than the sum of the terms. If, however, we agree that $H$ rather than $T$ is the true coefficient of $v$ in the first term, it will be found that in each of the two quoted cases, $v\,H$ absorbed about five-sevenths, and $n$ about two-sevenths of the total indicated power. Thus, whether we deduce it from practice or from theory, $v\,H$ appears to be the reasonable quantity. It is with reluctance that the writer differs from Mr. Murgue on any point, but if the imperfect as well as the perfect ventilator developed the theoretical depression, as Mr. Murgue claims,* the power developing such depression would be found in the steam-cylinder. But since the indicator fails to find it there, one is obliged to look elsewhere for the true value of the first term in the denominator of the fraction whose value is $e$. The writer considers that the indicated power is made up of three items: (1) The useful power expended in driving $v$ through the mine; (2) the useless power expended in driving $v$ through the fan; and (3) the further useless power expended on the passive resistances of the machinery. The sum of the first two is $v\,H$, or the total aerodynamic power; and the third is $n$, which includes all power over and above the aerodynamic. It is difficult to see how or why the total indicated power, $R$, can be either greater or less than the sum of these values.

The formula may now be reduced to its ultimate form. Already we have for the numerator, $p = v\,h$. But $h = H \cos^2 \phi$, and $v = V \sin \phi$, whilst $P = V\,H$; hence the numerator becomes $p = P \sin \phi \cos^2 \phi$. The denominator, $R = v\,H + n$. First substituting $V \sin \phi$ for $v$, and $P$ for $V\,H$; the denominator becomes $R = P \sin \phi + n$. If we now divide both numerator and denominator by $P$, the mechanical efficiency of any fan on any mine will be:

$$e = \frac{\sin \phi \cos^2 \phi}{\sin \phi + \frac{n}{P}} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (11)$$

Now, under the conditions already defined, $n$ is a constant for a given fan and its engine, provided that the minor conditions are normal. By the minor conditions, the writer understands the condition of the working parts, the state of lubrication, etc. The weights of the fan and its engine are constant; under the given conditions, their velocity is constant; and hence $n$ is constant. It is also evident that $P$ is constant; for the velocity and density

* *The Theories and Practice of Centrifugal Ventilating Machines*, page 59.

are constant under the conditions; and $P$ is merely an abstract standard of reference, having no actual existence except when the fan acts in the open air. Hence, if $n$ and $P$ be constant, the fraction $n/P$ is also constant; and $e$ varies only in accordance with the trigonometrical functions shown in equation (11). All variations in the size of the equivalent orifice, all consequent fluctuations in the volumes and pressures, and all the ultimate influences on the powers are measured in the trigonometrical functions of the variable angle $\phi$.

The formula (11) is an absolutely legitimate deduction from the theory of orifices; it is applicable in all cases where the original theory itself is applicable; and it extends the scope and practical utility of the fundamental principles laid down by Mr. Murgue. With the graphic application about to be shown, it enables one easily to trace the otherwise obscure influence of the equivalent orifice of the mine upon the mechanical efficiency of the fan; and permits one to determine the precise size of mine upon which any given fan will develop the maximum efficiency of which it is capable at the given speed.

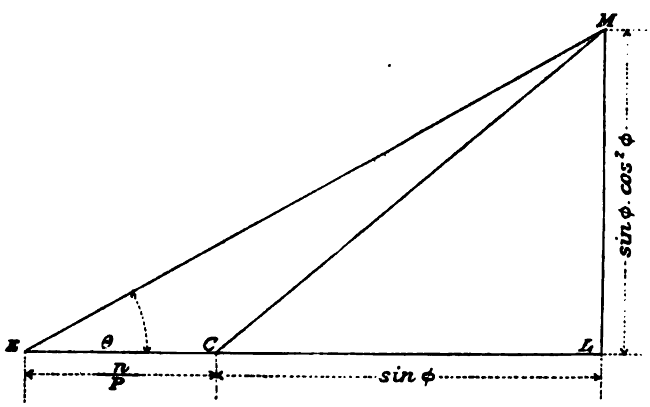


FIG. 1.

It will now be convenient to introduce the angle $\theta$, determining the efficiency of the fan, and to determine the precise influence of the angle $\phi$ upon the angle $\theta$. In Fig. 1, it is made sufficiently clear that, if $EC = n/P$, and $CL = \sin\phi$, whilst $LM = \sin\phi\cos^2\phi$, the formula (11) may be written

$$e = \frac{\sin\phi\cos^2\phi}{\sin\phi + \frac{n}{P}} = \frac{LM}{CL + EC} = \frac{LM}{EL} = \tan MEL.$$

Hence, if the angle $MEL$ is $\theta$ degrees, we have

$$e = \tan \theta. \qquad (12)$$

Now, if $n$ were *nil*, $n/P$ would also be *nil*; and the line $EC$ would be zero. Under these ideal circumstances, the triangle of the efficiency would be $MCL$; and $e$ would be equal to the tangent of the angle $MCL$. But

$$\tan MCL = \frac{LM}{CL} = \frac{\sin \phi \cos^2 \phi}{\sin \phi} = \cos^2 \phi.$$

Hence $\cos^2 \phi$ is the absolute theoretical limit of $\tan \theta$; whence the efficiency $e$ can never (even in theory) exceed $\cos^2 \phi$. This limit cannot be reached unless $n$ be *nil*, and since, in actual practice, $n$ is always a positive and real value, it follows that, in actual practice, $\tan \theta$ and the efficiency $e$ must always be less than $\cos^2 \phi$. The larger the magnitude of the angle $\phi$, the smaller is the value of $\cos^2 \phi$, and the narrower is the theoretical limit of the efficiency $e$. It is now evident that small fans can never be economical ventilators of large mines. By a large mine, of course, is meant a mine of large equivalent orifice, and by a small fan is meant a fan having a small orifice of passage. It is necessary, also, to remember that a fan of relatively small cubical contents may possess an orifice of passage greater than that possessed by a machine of much larger diameter and width. Thus one may compare the Schiele fan at Great Western colliery with the Guibal fan at Cwmaman colliery.*

$\text{Cos}^2 \phi$, however, is merely the theoretical limit of $e$ in the same way as $u^2/g$ is the theoretical limit of $h$. It is an ideal to aim at—an ideal to continuously approach, but not an ideal that will ever be actually realized. The practical maximum of $h$ is $H$, which is always less than $u^2/g$; and the practical maximum of $e$ is $E$, which is always less than $\cos^2 \phi$. Before considering the special case of $E$, however, we may consider a little more fully the general relationship subsisting between the angle $\phi$ of the orifices, and the angle $\theta$ in the efficiency-triangle. By way of illustration, conceive that under the predicated conditions in a certain fan, $n = 0{\cdot}2P$. We desire to know what pressure, $h$, volume, $v$, powers, $p$ and $p_0$, and efficiency, $e$, will be developed when this fan acts on a mine of such dimensions that $a/o = 0{\cdot}4$. It is, of course, assumed that the orifice of

* Mr. M. Walton Brown on "Mechanical Ventilators," *Trans. Inst. M.E.*, vol. xvii., page 517.

passage, and the provisional constants, $H$, $V$ and $P$, have already been determined by the fundamental theory.

The question can be solved graphically as shewn in Fig. 2. First, draw a square, $ABCD$, making its side equal to unity. Produce $AC$ to $E$, making $CE = n/P$. Mark off on the vertical line, $DB$, a length, $DF = a/o$, join $CF$, and the angle, $FCD$, is equal to the angle $\phi$. From $D$, draw $DG$ perpendicular

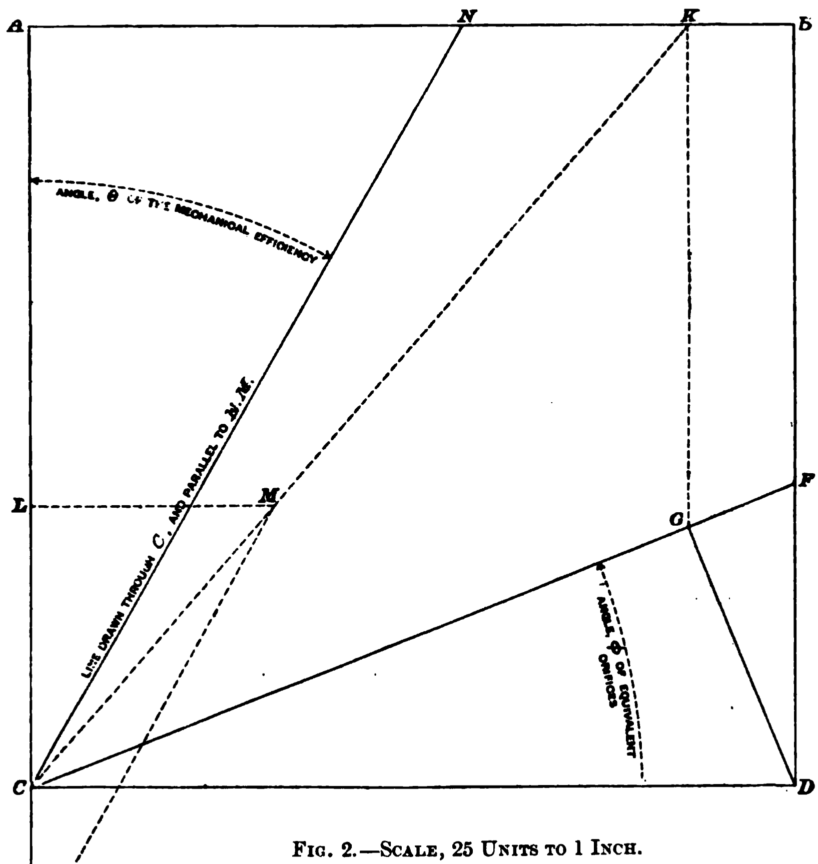


FIG. 2.—SCALE, 25 UNITS TO 1 INCH.

to $CF$. Then $DG = \sin\phi =$ the ratio of $v$ to $V =$ the ratio of the total aerodynamic power to $P$. From $G$, draw the vertical line $GK$. Then $AK = \cos^2\phi =$ the ratio of $h$ to $H$. Join $CK$ by a dotted line. Now take a point, $L$, in the line $CA$, and make $CL = DG$. From $L$ draw a horizontal line intersecting the radial line $CK$, at $M$. Then $LM = \sin\phi\cos^2\phi =$ the ratio of $p$ to $P$; and $p_0 = P\sin\phi - p$; or, $CL - LM =$ the ratio of $p_0$ to $P$.

Next join $EM$, the triangle $MEL$ is the efficiency-triangle, and the angle $MEL$ is the angle $\theta$. Draw $CN$ parallel to $EM$; the angle $NCA$ = the angle $MEL$ = the angle $\theta$; and $\tan \theta = AN/CA$. But, $CA$ = unity; therefore, $\tan \theta = AN$ = the efficiency of the fan.

Measuring off these several lines on the appended scale, we obtain the following solution to the given problem:—When $a = 0{\cdot}40o$, and $n = 0{\cdot}20P$, then $h = 0{\cdot}86H$, $h_0 = 0{\cdot}14H$, $v = 0{\cdot}37V$, $p = 0{\cdot}32P$, $p_0 = 0{\cdot}05P$, $p + p_0 = 0{\cdot}37P$ = the aerodynamic power, $p + p_0 + n = 0{\cdot}57P$ = the indicated power of the engine, and $e = 0{\cdot}56$, or 56 per cent.

It is clear (1) that the preceding results are obtained more easily by the graphic method than by calculation; and (2) that the values of $h$, $v$, $p$ and $e$, will vary with every change in the magnitude of the angle $\phi$. It may now be enquired whether any method can be devised to ascertain easily at what particular magnitude of the angle $\phi$ the angle $\theta$ becomes a maximum under any given ratio of $n$ to $P$. In other words, on what particular equivalent orifice will a given fan running at a given speed attain its maximum efficiency, $E$?

It has already been stated that ($\sin \phi \cos^2 \phi$), the numerator of equation (11) attains its maximum value when $\phi$ equals 35¼ degrees; and the denominator $\left(\sin \phi + \dfrac{n}{P}\right)$ is a rising value throughout the quadrant. Hence no fan whatever can attain its maximum efficiency when the angle $\phi$ is greater than 35¼ degrees. When $\phi$ = 35¼ degrees, $a/o = 0{\cdot}70$; but since between 25 and 35 degrees, $\sin \phi$ increases much faster than its product by $\cos^2 \phi$, it will presently be seen that no fan, having $n/P$ of any practically possible value, can attain its maximum efficiency on any mine, where $a$ is greater than $o/2$. And although there are many fans that will give a good efficiency, when $a/o = 0{\cdot}5$, there are no good fans that will give their maximum efficiency when the ratio of $a$ to $o$ is even so large as that. These statements will be presently justified, and in the meantime the writer asks members to accept provisionally his assertion that it is of no use to seek for maximum efficiencies on equivalent orifices greater than $o/2$. And it is of as little use to look for maxima on equivalent orifices which are less than $o/4$. Efficient fans may frequently give high results outside these limits, but no fan, good or bad, will yield its maximum

efficiency if $a$ is greater than $o/2$, or less than $o/4$. If $a$ is made greater than $o/2$, the theoretical limit ($\cos^2 \phi$) is too much reduced; whilst, if $a$ be less than $o/4$, $\sin \phi$ becomes too small, and $n/P$ becomes the dominant quantity in the fraction denoting the mechanical efficiency, $e$. These statements are more easily substantiated by means of a diagram.

Referring again to Fig. 2, it will be recognized that if the diagram were filled with a large number of values of the angle $\phi$, we should obtain a number of lines, $LM$, $L_2M_2$, $L_3M_3$, etc. These ordinates are those of $p$, and in such a diagram the points $M$, $M_2$, $M_3$, etc., would form a curve, which would be the curve of the useful power, $p$, in the air. The value of $n/P$ would not affect the position of the points $M$, $M_2$, $M_3$, etc., though it would affect the angle subtended by the ordinate $LM$. The points $M$, $M_2$, $M_3$, etc., are therefore fixed by the angle $\phi$, whilst the angle $\theta$, subtended at $E$ by any ordinate, $LM$, is governed by the length of $CE$, or the value of $n/P$. Hence the curve of $p$ has the same position relatively to the point $C$ in all cases; but its position relatively to the point $E$ is governed by the value of $n/P$, or the length of $CE$. Hence for all fans, the triangle $MCL$ is the same, and the curve of the points $M$, $M_2$, $M_3$, etc., is the same, but for any particular fan, the efficiency triangle $MEL$ is governed by the length of $CE$, or $n/P$.

Fig. 3 shews the curve of volumes, $DJR$, the curve of pressures, $DGQ$, and the curve of useful power, $CMW$, carried as far as 45 degrees of angle $\phi$. By this diagram, the maximum efficiency under any given value of $n/P$ may be found, together with the circumstances of orifice, pressure, volume and power, under which such maximum efficiency obtains. Suppose that $n = 0{\cdot}04P$, then $CE = n/P$. The object is to find which ordinate, $LM$, of the curve, $CMW$, subtends the greatest angle, $\theta$, at $E$; and it is perfectly clear that the angle subtended at $E$ attains its maximum when the hypotenuse, $EM$, of the triangle $MEL$, lies as a geometrical tangent on the curve, $CMW$. For if it lies outside the curve, there is no angle $\theta$, as that angle must be subtended by an ordinate of the curve; and if it cuts the curve, the angle, $\theta$, is less than when the hypotenuse merely touches the curve. But if the hypotenuse touches the curve, the angle, $\theta$, subtended by the ordinate at the point, $M$, of tangential contact, is the maximum angle that can be subtended

at $E$ by any ordinate, whatever, of the curve. This tangent touches the curve at $M$; and produced both ways it runs to $E$ and $T$. The parallel on $C$ of $EMT$ runs to $N$; and the maximum efficiency, $E = \tan\theta = \tan NCA = 0{\cdot}82$ *

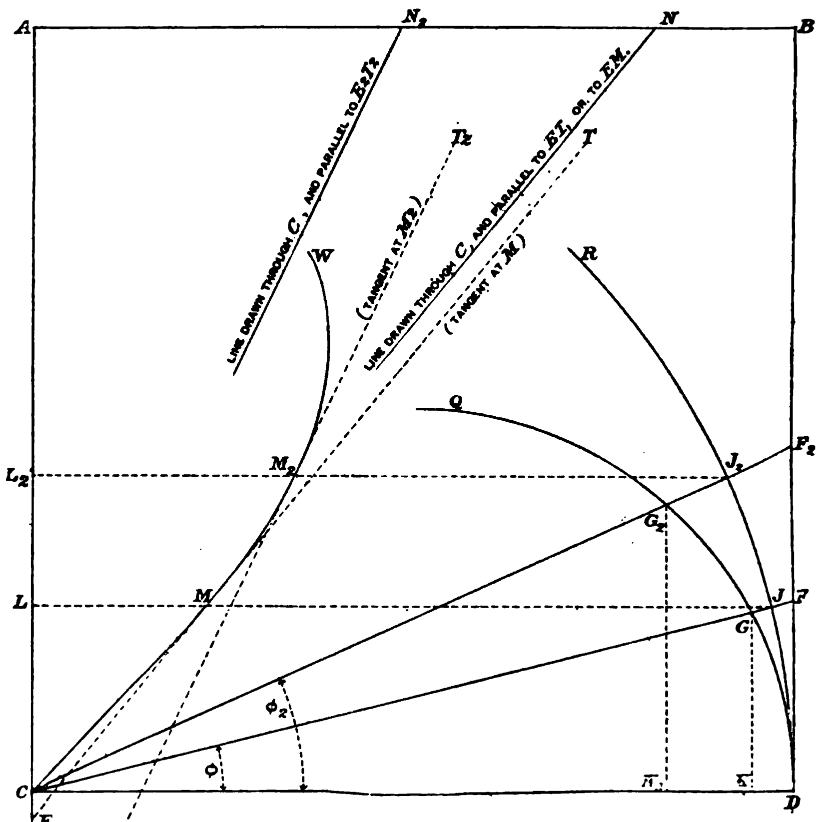


FIG. 3.—SCALE, 25 UNITS TO 1 INCH.

To find the orifice on which the maximum efficiency, $E = AN$, occurs, draw a horizontal line, $LJ$, through the point of tangency, $M$; cutting the curve $DJR$ at $J$; and through $J$, draw a radial line, $CF$. Then $a_{,}o = DF = 0{\cdot}25$. The radial line, $CF$, also intersects the curve of pressure, $DGQ$, at $G$. Draw a line, $GK$, perpendicular to $CD$.

* In order to preserve the clear outline of the curve, $CMW$, the tangents, $ET$ and $E_2T_2$, are not drawn at the points of contact, $M$ and $M_2$. The lines drawn parallel to $ET$ and $E_2T_2$ pass through the point $C$.

Then $CK = h/H = 0{\cdot}95$. From the principles already laid down, it will further be clear that $v/V = CL = 0{\cdot}24$, and that $p/P = LM = 0{\cdot}23$. This is the case of the maximum efficiency, $E$, when $n = 0{\cdot}04P$ in any fan. In this case, $E = 0{\cdot}82$; and is obtained when $a = o/4$.*

Using the same reference-letters and distinguishing by an inferior figure, we have in the same diagram the case of the maximum efficiency when $n/P = CE_2 = 0{\cdot}30$. The point of tangency appears to be at $M_2$; the tangent on $M_2$ is $E_2M_2T_2$; its parallel on $C$ runs to $N_2$; and, in this case, the maximum efficiency is $AN_2 = 0{\cdot}48$ or $0{\cdot}49$. It is obtained when $a/o = DF_2 = 0.46$; and the corresponding values of $h$, $v$, and $p$ are shown respectively by $CK_2$, $CL_2$, and $L_2M_2$.

It would perhaps confuse the diagram too much if the third case were inserted, but the subjoined statements may be followed and proved by merely laying a straight edge to the various points on the curves. If we take the case where the maximum efficiency occurs under the condition that $a = o/2$, we can work back to the value of $n$, which necessitates so high a value of the angle $\phi$. Make $DF_3 = a/o = 0{\cdot}50$, and draw a radial line, $CF_3$. It cuts the curve of volumes, $DJR$, at $J_3$. The point of tangency, $M_3$, on the curve of power, $CMW$, lies on the same horizontal line as $J_3$. The tangent on $M_3$, when produced, will cut the line $AC$ at $E_3$; and $CE_3 = 0{\cdot}50 = n/P$ in this case. Drawing through the point, $C$, a parallel line to the tangent, $E_3M_3T_3$, it runs to $N_3$; and $AN_3$ is nearly $= 0{\cdot}38$. Hence the maximum efficiency obtainable when $n =$ half $P$, or when $n/P = 0{\cdot}50$, is less than 38 per cent.; and is obtained when $a/o = 0{\cdot}50$; or, when $a = o/2$.

We may assert that all the efficiencies likely to be obtained or tolerated in practice lie between the limits of $0{\cdot}38$ and $0{\cdot}82$; and, if so, it is clear that all the maxima of the efficiencies occur on equivalent orifices ranging between the limits of $a = o/4$ to $a = o/2$. As already stated, many fans will give good efficiencies outside these limits of $a$; but no fan having any reasonable or ordinary value of

* The exact point of tangency cannot be made absolutely clear, unless the curve be drawn to a very large scale. The numerical values are, therefore, somewhat approximate; but they may be relied upon as containing not more than 1 per cent. of error; which is near enough for practical purposes.

$n$ can yield its best work or its maximum efficiency outside the limits named.

Now, if all the maxima of the efficiencies are confined to equivalent orifices not greater than $o/2$ nor less than $o/4$, it follows that any fan whatever will work up to within 2 or 3 per cent. of its maximum efficiency when it works on an equivalent orifice, $a$, whose value is approximately $o/3$. Of the fans above used by way of illustration, we have at one end of the scale a poor machine having $n$ equal to $0{\cdot}5\ P$, and finding its maximum efficiency of less than 38 per cent. on an equivalent orifice $a = o/2$. But if the same fan were put on an orifice equal to $o/3$, it would (by equation 11) still yield an efficiency of 35 per cent.; or an efficiency only 3 per cent. less than the maximum. Returning to the other end of the scale, we have a pretty machine having $n = 0{\cdot}04P$, and finding its maximum efficiency on an equivalent orifice $a = o/4$. Here, the efficiency attains the high value of 82 per cent. But if the same fan were put on a mine where $a = o/3$, it would still give an efficiency of 80 per cent., or 2 per cent. less than the maximum.

It thus appears very safe to make a convenient generalization and say that in erecting a fan to ventilate any particular mine, the mining engineer cannot go far wrong if he designs his fan so that its orifice of passage shall be three times as large as the equivalent orifice of the mine. It will be evident that if the value $o/3$ gives almost the same results as the orifices of the maxima at the extremities of the scale, the results will depart even less from the maxima obtainable on orifices nearer to $o/3$.

From the fact that $o/3$ gives nearly the same results as any value between $o/2$ and $o/4$, it might be thought that the size of the equivalent orifice, after all, affects the efficiency but little. But the results appertaining to the value $o/3$ approximate in this way only to those obtained within the limits of the maxima, namely, between the limits of $a = o/2$ and $a = o/4$; and if we pass outside these limits, the efficiencies rapidly diminish. For example, if the fan, which gives a maximum efficiency of $0{\cdot}82$ when $a = o/4$, and an efficiency of 80 per cent. when $a = o/3$, be put on a mine where $a = o$, the efficiency will (by equation 11), fall to 47 or 48 per cent.

The writer concludes from this extension of Mr. Murgue's theory that:—(1) All fans develop their maximum efficiency on

equivalent orifices not less than $o/4$ and not greater than $o/2$; and (2) that any fan will work up to within 2 or 3 per cent. of its maximum efficiency, if the relation between the mine and the fan be such that $a = o/3$ or $o = 3a$. These conclusions appear to be of value providing that they are true; and they cannot be false if the equivalent-orifice theory be true. Most mining engineers, qualified to form an opinion on the matter, believe that the theory of the equivalent-orifice is reliable, and the present writer would never have troubled to construct this extension of the theory had he entertained the slightest doubt about the soundness of his premises.

The results set forth in this paper are the fruit of several years' study of this vexed question, and the work has frequently been pursued in face of many difficulties; but if the conclusions arrived at should prove as interesting to other members as they have been to the writer, he will feel that his labour has not been altogether without reward.

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Mr. M. Walton Brown said that some years ago he adopted a theory as to the appropriateness of a fan to a mine, dependent upon the ratio that existed between the orifice of the mine and the orifice of discharge of the fan,* and he was glad to find that Mr. Halbaum had been able to give mathematical reasons for the correctness of what he (Mr. Brown) had deduced, namely, that to obtain the maximum efficiency in the ventilation of a mine the orifice of the mine should lie between one-half and one-third of that of the fan.

Mr. S. F. Walker said that he was struck with the similarity of the arguments and reasonings used by Mr. Halbaum when working out his theories, and the methods adopted in electrical work. So far as he had been able to gather from the paper, there was exactly the same series of laws and conditions, only air was driven in one case and electricity in the other. For instance, when a dynamo was delivering current for electric lighting by incandescent lamps, there were frictional losses in driving the machine, air-friction of the armature, etc.; there was also the charge for conversion of the mechanical energy into electrical energy and the

* *The Colliery Manager's Pocket-book*, 1891, page 271.

magnetism to be supplied, and the electric current say passing round the field-magnet and armature converted into heat. These were the total losses or charges; and outside these they had the useful current which was delivered to the lamps. In the case of the fan, there was the friction of the engine, which was common to both; there was the mechanical friction of the fan and the friction of certain portions rubbing against the atmosphere; there was the charge for conversion, what Mr. Halbaum called "useless pressure" generated within the fan itself; and the pressure required to drive the air through the fan, which was similar to the initial pressure in driving the machine in the case of electrical power. But the comparison seemed to go farther. The laws of continuous currents were very simple with a given pressure; the current which was got through depended directly on the size of the conductors, which was practically equivalent to the size of the air-passage. The question arose, "where does the energy go?" It could not be lost, for by the law of the conservation of energy the energy used up in driving the air through the fan could not be lost, just as the energy used up in driving current from the dynamo could not be lost. Though the dynamo in converting the energy used up a certain portion, which was converted into heat, and similarly the energy used in the fan was also converted into heat. Further, a certain amount of energy was used, apart from the engine and the length and periphery of the roads through which the air had to pass, and this also, it appeared to him, was converted into heat in the same way as the loss to which they were subject with electric currents when delivering through a long length of main cable—a certain quantity of energy was used up on the way; it started as electricity and came out as heat. In the course of investigations in electrical work, a great many things which appeared originally as resistance—that was to say, merely a sort of passive opposition to current—were really back-pressure; for instance, in an arc-lamp the amount of pressure—the voltage required to drive the current through the lamp to give a certain light—was made up of two quantities, the resistance of the carbons and of the gaseous matter in the arc; but by far the larger portion was the back-pressure created by the arc itself at the point where the conversion into heat took place. He thought that there would be a good many back-pressures set up in the mine, and that this would account

possibly for some of the little awkward points met with. In electrical work it was found to be so. He presumed when air was driven against a face back-pressure was set up, and it was necessary to overcome that back-pressure to get the air to pass on; further, the friction created by the air in passing along the sides and roofs was also back-pressure. This back-pressure might not amount to much, but it had to be overcome and the true pressure would be made up, if that were so, of two quantities; one, the back-pressure as in the case of electricity, and the other the true passive resistance of the air-passage. He was also struck with the way in which Mr. Halbaum had worked out his mathematical diagrams and the value of a trigonometrical function when one got it. When they got two sides of an angle, or any other relation, as ordinates to each other, it was wonderful what could be done with them. When they could be laid down graphically, it became very much easier to use a scale, for when two lines were found to come nearly into line with each other if there was a small piece crossing they could for practical purposes leave it out, as the diagram would show it to them.

Prof. H. STROUD (Durham College of Science) had carefully read Mr. Halbaum's extension of the equivalent-orifice theory, which was a continuation of a former paper by the same author. The graphical method of treatment had been very clearly and ingeniously worked out by the author, and the results which he deduced would be of considerable interest to all concerned with fan-ventilation.

Mr. D. MURGUE (St. Etienne) wrote, with reference to the extension of the equivalent-orifice theory, that he had been interested in the very judicious remarks made by Mr. Halbaum on the subject of the difference that was observed in certain ventilators between the total power in the air calculated by the formula $vT$ and the indicated horsepower, $T$ being the theoretical depression $u^2d/g$. It should be remembered that this value of the theoretical depression is only applicable to ventilators with radial blades—that is to say, placed in the direction of the radius. When the blades are inclined backwards, as in the case of the ventilators at Craghead and Great Western collieries, the theoretical depression expressed in water-column contains a negative expression and is

only equal to $T = \frac{u^2 d}{g} - \frac{u V_2 \cos a\, d}{g}$, $V_2$ being the relative velocity of the air upon the blade and $a$ its inclination.* This should explain the anomaly noted by Mr. Halbaum, but there is also another cause, arising from the fact that the volumes of air measured by revolving anemometers are always more or less exaggerated. He trusted that this explanation would afford assistance to Mr. Halbaum.

Mr. J. S. DIXON (Bothwell) agreed that back-pressures did take place in air-ways the same as in electric cables, but there was a good old theory in regard to airing colliery-workings, and that was to have large air-ways and plenty of them: this would overcome the difficulty, and was the secret of successful ventilation. The paper was of a highly scientific kind and deserved careful study, and he had great pleasure in moving a vote of thanks to Mr. Halbaum.

The CHAIRMAN (Mr. H. C. Peake) seconded the vote of thanks, which was cordially approved.

Mr. H. W. HALBAUM wrote that he was obliged by the remarks offered in criticism of his paper, but they left little for him to answer. It might be true, as Mr. Dixon had said, that large airways and plenty of them constituted a good old theory, but the oldness of such a theory was more conspicuous than its goodness. If the members considered the case of an exhausting fan at work on a mine, they would readily see that the fan bore precisely the same relationship to the mine that a pump bore to its suction-pipe. If, therefore, they enlarged the mine-airways, they simply enlarged the diameter of the suction-pipe. And the general and never-failing remedy for every difficulty encountered in pumping was not a suction pipe of unlimited diameter. As engineers, they would consider the pump and its suction-pipe together; and as engineers, they must also consider the fan and the mine together. It might be freely admitted that larger airways and more of them would always increase the volume of the ventilation, but unless the resistance of the mine was vastly, say ten or twenty times, greater than the resistance of the fan, the increased volume would

* *Bulletin de la Société de l'Industrie Minérale*, series 2, 1880, vol. ix., pages 22 and 71.

not be obtained in the most economical way; and really successful ventilation, as they all knew, included economy, as well as efficiency in the matter of volume. Taking a mine of less resistance, the principles set forth in his paper showed that, supposing the resistance of the mine to be only twice that of the fan, any further enlargement of the mine airways would bring the following results: (1) The volume of the ventilation would be increased; (2) the cost per unit of useful work would be increased; and (3) the total quantity of useful work would be reduced. The position might be stated thus: If the air was throttled in the mine they might increase the area and number of their airways and do well; but if the air was throttled at the fan, they might act on that theory and do very badly, and Mr. Murgue's theory of the equivalent orifice showed that the diameters of the pump and of the suction-pipe should be in reasonable proportions the one to the other, if efficiency on the one hand, and economy on the other, were desired.

With respect to Mr. Murgue's communication, he was aware, from a careful study of that gentleman's writings, of the negative term in the formula for the theoretical depression. But, having regard to the convenience of a common standard of reference, he had always followed Mr. Murgue's own method of taking $u^2/g$ as the standard for all fans, whatever, and allowing the negative term to find its effect in the manometrical efficiency obtained when the initial depression was divided by $u^2/g$; and that omission would certainly account for some of the difference between Mr. Murgue and himself. He did not know, but would shortly ascertain, whether it accounted for the entire difference. His present impression was that it did not, although he agreed with Mr. Murgue regarding the difficulty of obtaining accurate measurements by means of ordinary revolving anemometers. It was with very great reluctance that he ventured to question the soundness of any single position occupied by such an undoubted authority as Mr. Murgue, and he appreciated very much that gentleman's good-natured reception of the criticism he had presumed to offer.

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Mr. W. DENHAM VERSCHOYLE's paper on "Gold-dredging" was read as follows:—

# GOLD-DREDGING.

By W. DENHAM VERSCHOYLE.

The author has not observed, in the *Transactions*, any papers dealing with the modern development of this important branch of mining, and he thinks, therefore, that a few notes on the subject may prove interesting. His experience has been confined to the Australasian colonies, and he presumes that engineers from California and other parts of the world will be able to add to the information contained in this paper.

Gold-dredging is important, as providing a practical method of dealing with sundry alluvial deposits, either entirely or economically unworkable by means of hydraulic sluicing, elevating, or other methods.

Grab-, suction- and bucket-dredges have been tried; and practice has shown that the two former cannot compete with the latter method, in point of economy and general efficiency, for treating ordinary gravels and boulders. In fine sand containing timber they may, however, occasionally prove useful.

In New Zealand steam-dredging for gold began in 1882 with the launching of the Dunedin dredge. Prior to that date, much work had already been done; but looking back now, he could only designate the operations carried on up to that time as experimental, elementary and generally unsuccessful. They were valuable, however, because they led up to and made possible the dividend-paying machine of to-day.

The most important innovation introduced by New Zealand engineers is the elevator for stacking away the tailings in the rear of the dredge. The gold-bearing spoil is raised by the buckets, and shot into a long, revolving, perforated and inclined steel cylinder, down the centre of which is a large pipe from which jets of water play on the spoil, as it is slowly revolved

by the cylinder. By the time that the spoil has travelled to the end of the cylinder, all the gold-carrying stuff has been washed through the perforations on to the gold-saving tables (Figs. 1 and 2, Plate XIII.).*

Formerly, the coarse gravel and stones, which could not pass through the perforations, after traversing the cylinder, were dumped overboard at the stern of the dredge It soon became apparent, however, that the efficiency of a dredge was limited by the depth of the intersection of the faces of the worked and unworked gravel, and as a solution of this difficulty, the elevator was introduced, with most satisfactory results. The elevator, as now developed, varies much in the shape of the buckets and the methods of staying and driving: various patterns being favoured by different engineers, but they must be guided to a certain extent by the class of work to be done.

The revolving screens are made of ½ to ¾ inch steel plate, with ½, ¾ or 1 inch perforations. The diameter is generally about 4 feet, the pitch 1 to 1½ inches to the foot, and the length from 15 to 30 feet. There is an iron collar at each end, which rests on two small friction-wheels, and motion is given positively, or preferably by friction-driving from one of the wheels, which is itself belt-driven from the main engine.

The main bucket-ladder, buckets, and main gearing are very similar to those in use on any ordinary dredge.

The winch is a very important part of the dredge, and consequently much ingenuity has been expended on its improvement. The winchman controls the movements of the dredge forward, backward and laterally, and also raises and lowers the bucket-ladder. This is all done by one sixway-winch, in which accessibility, compactness and instantaneous action are the main features desired.

Close beside the winchman, there is generally a lever for throwing the buckets in or out of action by means of a friction-clutch. This appliance is very necessary in ground containing boulders or timber.

The hull was formerly built in two separate pontoons, one on each side of the bucket-ladder; but modern hulls are, almost universally, built as one pontoon, with a well for the ladder

* This plan is taken from *Papers and Reports relating to Minerals and Mining, New Zealand*, 1896, C.-3, page 154.

in the centre. In large rivers, where there is a swift current and numerous boulders, it is well to have several watertight partitions.

To ensure continuous action as nearly as possible, and a long life to a dredge, the following points require special attention. The top and bottom tumblers of the main bucket-train and elevator should be made in as few pieces as possible, and of cast-steel. The main gearing should be made of cast-steel. The bushes and connecting-pins of the main bucket-chain and the elevator should be made of manganese-steel, or some other hard steel. The buckets should be provided with interchangeable steel lips. For working in stony ground, at least two buckets should be omitted, and steelshod grabs put in their place.

A large supply of water is required for thoroughly washing the spoil, and it is generally supplied by a centrifugal pump belt-driven from the main engine.

The power required on a dredge is determined by the depth and quality of the wash and the size of the buckets. A dredge having 7 cubic feet buckets capable of working 50 feet below water-level and elevating the tailings to a height of 40 feet, would require a 25 nominal horsepower engine, and as supplementary engines are required for the winch and electric-light dynamo, the boiler should be about 40 nominal horsepower.

The small pebbles and sand, which pass through the perforations of the revolving-screen, fall direct on to the gold-saving tables: these are covered with cocoanut-matting, expanded metal, and various forms of riffles. The matting is taken off at intervals, and washed in suitable tubs provided for the purpose. There is no doubt that a considerable percentage of gold is lost, and improvements are therefore required in the gold-saving part of the plant. These will probably take the form of a stuffing box, to deliver the spoil more evenly upon the tables and probably, also, where the gold is fine, a system of re-elevation and retreatment of the finer sands by gravitation or chemical methods, will be adopted.

Almost any ground may be dredged if a constant supply of water be assured, either by a small stream or by dams, and we may therefore divide dredges into two distinct classes, varying as to their design, material, etc., namely, river-dredges and dry-land dredges.

Considered financially, the land-dredge can generally be made a safe investment, by judicious prospecting, as its operations are confined to accessible beaches and flats. The river-machine is generally more speculative, as prospecting is often out of the question, owing to the large volume of water, the proximity of old workings or gold-bearing terraces alone giving a clue as to the probabilities of payable wash in the bed of the river.

Thorough prospecting is of vital importance, where a large outlay on machinery is contemplated. Several important points must be determined by methods which must be adapted to local conditions, namely:—(*a*) The value per cubic yard; (*b*) the class of wash; (*c*) the average depth of ground; (*d*) the percentage of ordinary sand, surface-silt and heavy mineral sand; and (*e*) the position of the water-level with reference to the surface and to the bottom. The importance of (*a*) is obvious and (*b*), (*c*), (*d*) and (*e*) will determine the size of buckets, length of ladder and elevator, spread of tables and quantity of water, which will enable the ground to be worked to the best advantage.

Shafts should be sunk at various points, and a careful record should be kept of the points previously enumerated. If there is sufficient water taken from the shaft, the excavated material may be run straight through an ordinary sluice-box with matting, riffles and expanded metal. With a proper arrangement of screens, the percentage of light sands can be estimated, and the washings from the mats will give an approximation for the heavy sands.

If dish-prospecting shows that the gravels are rich in fine gold, they should be treated by gravitation-methods. If the loss is found to be great, it should be determined by chemical analysis, and the advisability of providing—for the dredge—concentrators and a potassium-cyanide plant should be considered. If there is a large influx of water to the shaft, a pump will be necessary, in which case a centrifugal pump, 3 or 4 inches in diameter, with a telescopic length of piping and a foot-valve, will be found useful. If the sinking is through loose sand, telescopic cylinders, that can be withdrawn and moved about, will often be found cheaper than timber. If the bottom cannot be reached by a shaft, on account of water, nor the depth calculated from the dip of strata or other means, a bore-hole should be made, as it is

very important that the full depth should be known. In fine gravels, a steel rod, or small pipe, can often be hammered or jumped down.

Having ascertained the average depth of the ground below water-level the length of the bucket-ladder will be $\sqrt{d^2 + d^2}$ where $d$ is the average depth below water-level plus the height of the top pin (generally about 15 feet) above water-level. This length enables the majority of the work to be done at the best possible angle of inclination, namely, 45 degrees.

A field-book should be kept in the form shown in Table I.

TABLE I.—FIELD-BOOK.

| No. | Shafts. Surface-dimensions. | Shafts. Depth. | Remarks on Strata, and Nature of Bottom. | Material excavated. | Gold saved. | Remarks on Gold. | Water-level. | Total Gold: average per cubic yard. | Coarse Wash arrested by Screen. | Heavy Sands off matting. | Light Sands. | Percentage to be passed over Tables. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ft. Ft. | Ft. | | Cub. Ft. | Grs. | | | Grs. | C. Ft. * | C. Ft. * | C. Ft. † | |
| 1 | 2·5 × 4 | 3 | Clay ... .. | 30 | 0 | — | 3 feet from surface and 20 feet from bottom | 11·9 | 153 | 40 | 37 | 33 |
| | | 4 | Fine wash ... | 40 | 8 | Fine | | | | | | |
| | | 6 | Coarse wash and boulders, largest 2 feet in diameter | 60 | 43 | Coarse shotty | | | | | | |
| | | 10 | Fine wash. Bottom, finely laminated schist, strike north 23 degrees & dip 45 degrees west | 100 | 51 | Floury | | | | | | |
| | | 23 | | 230 | 102 | | | ‡ | | | § | ‖ |

* Measured. † Calculated.

‡ 102 × 27 ÷ 230 = 11·9. § 230 − (153 + 40) = 37. ‖ 230 : 40 + 37 = 100 : 33.

If dish-prospects show a big loss of fine gold in the light sands, and in the heavy sands after amalgamation, bulk-samples should be saved for laboratory-treatment by potassium cyanide or other methods.

If a large-scale chart is prepared of the area to be operated, showing the shafts, it, together with the field-book, will be found very useful, the progressive position of each dredge when working being marked thereon.

From the information obtained in sinking shafts the principal dimensions of the dredge can be fixed. The capacity of the gold-saving apparatus is the first consideration, and the other parts then in proportion. The proportion of sand and water passed over each foot in width of the table, is an important factor in the success, or otherwise, of the dredge; and it is particularly so in old littoral deposits containing a large percentage of titanic iron-sands. In this class of wash, a distributing head-box, a large supply of water, also tables adjustable as to fall, and with strakes that can be cleaned up separately, should be provided. The proportion of sand to water should be about as 1 to 20; the minimum flow of water 10,000 cubic inches per minute per foot of table-width; and the sand maximum for the same about 2,000 cubic inches. The table-fall should be adjustable between the limits of 1 to 2 inches per foot, by wedges or screws.

Power is, of course, usually derived from coal or fire-wood, but in the case of a company operating a large fleet of dredges within the radius of a few miles, a large central electric-plant utilizing either coal, wood, or water-power, may be found suitable and advantageous, from many points of view.

The writer will now give an estimate of the cost of treating a cubic yard of gravel with a large, modern dredging-machine, under average conditions. With a bucket-capacity of 7 cubic feet, speeded for the delivery of 10 buckets, 0·75 full, per minute, the delivery will be 115 cubic yards per hour, and 14,490 cubic yards per week.

The cost of running for a week will be:—

| | |
|---|---|
| 6 men at 10s. per day for 6 days | £18 |
| Manager ... ... ... ... | 4 |
| Coal, varies very greatly, say— | 15 |
| Oil, waste, etc. ... ... ... | 1 |
| Repairs ... .. ... ... | 5 |
| Office-expenses, say— ... ... | 10 |
| Total | £53 |

And the cost of treating a cubic yard will be 0·87d. With gold at £3 17s. 6d. per ounce, the profits on working ground worth 1s. 11·05d. or 11·9 grains, as per extract from log given in Table I., would be:—(23·05d. − 0·87d. = ) 22·18d. per cubic yard; and (14,490 × 22·18 = ) £1,339 2s. 4d. per week.

The cost of a dredge to do this work would be under £10,000 in any manufacturing centre.

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The CHAIRMAN (Mr. H. C. Peake) said that this interesting paper showed how far afield the Institution extended. The profits referred to seemed somewhat astonishing—£60,000 or £70,000 on an outlay of £10,000. At the same time, the cost of working seemed remarkably small, as also was the manager's salary. He had pleasure in moving a hearty vote of thanks to Mr. Verschoyle for his interesting paper.

Mr. BENNETT H. BROUGH, in seconding the vote of thanks, said that the figures given in the paper differed somewhat from those published elsewhere. A valuable report by Mr. Jaquet had been published by the New South Wales Government in which the cost of gold-dredging in Montana was given as 4½d. per cubic yard against somewhat less than 1d. mentioned by the writer of the paper. That 4½d. was the cost of using steam; with electricity, which was now largely adopted in Montana, the cost was about 2¼d. per cubic yard, and he believed that about 98 per cent. of the gold was saved. Undoubtedly, this method was an important advance in the working of alluvial deposits, and even if the author's figures were a little optimistic, it could be no doubt carried out at a remarkably low cost; in fact, in some of the New Zealand gold-dredging operations, a dredge costing from £5,000 to £10,000 had repaid its entire cost within six months.

The vote was cordially approved.

Mr. W. DENHAM VERSCHOYLE wrote that since writing his paper, he had been travelling through British Columbia. Numerous attempts had been made to dredge the rivers of that colony but up to the present time no successful operations, for any length of time, had been recorded. He thought that the want of success was principally owing to the class of dredges that had been built. With few exceptions, they had been of the grab, suction or dipper type. These had all been tried in New Zealand, and had been discarded many years ago, and when the same thing had been done in British Columbia there was every probability that dredging would be successful.

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Mr. J. MALCOLM MACLAREN'S paper on "The Charters Towers Gold-field, Queensland," was read as follows:—

# THE CHARTERS TOWERS GOLD-FIELD, QUEENSLAND.

BY J. MALCOLM MACLAREN, B.Sc.

*Introduction.*

The Charters Towers gold-field, the most important in Queensland, is situated in south latitude 20 degrees 3 minutes and east longitude 146 degrees 18 minutes. Its seaport is Townsville, in Cleveland Bay, 82 miles distant by rail. The township has risen round the principal mines, and has a population of some 25,000, all entirely dependent on the mining industry. For its position, lying, as it does, well within the tropics, it is a remarkably healthy town; but it was not always so. In former years it was subject to visitations of enteric fever, so common in all newly-formed Australian mining-camps. With the introduction, however, of a pure water-supply pumped from the Burdekin river, 8½ miles away, this scourge has almost completely disappeared. The climate is decidedly warm, but not unbearably so, though the summer temperature may range up to 110° Fahr. in the shade. The rainy season, the duration of which, of course, exercises a potent influence on milling operations, may occur during any or all of the first three months of the year, and is generally preceded in December by tropical thunderstorms with accompanying rainfall. The remaining months of the year are practically rainless.

As a gold-field, Charters Towers has not yet passed out of its third decade. It was discovered, in 1872, by Messrs. Mosman, Clarke and Fraser. It owes its name partly to Charters, the warden of the then important gold-field of Ravenswood, and partly to an unfortunate corruption of "tors," the Devon term of such granite-outcrops as those that served as landmarks to the original party of prospectors, and at the base of which was found the alluvial gold that occasioned the first "rush." With the exhaustion of the small patches of alluvium came the discovery of the auriferous reefs, the development of which has steadily progressed to the present day, with the result

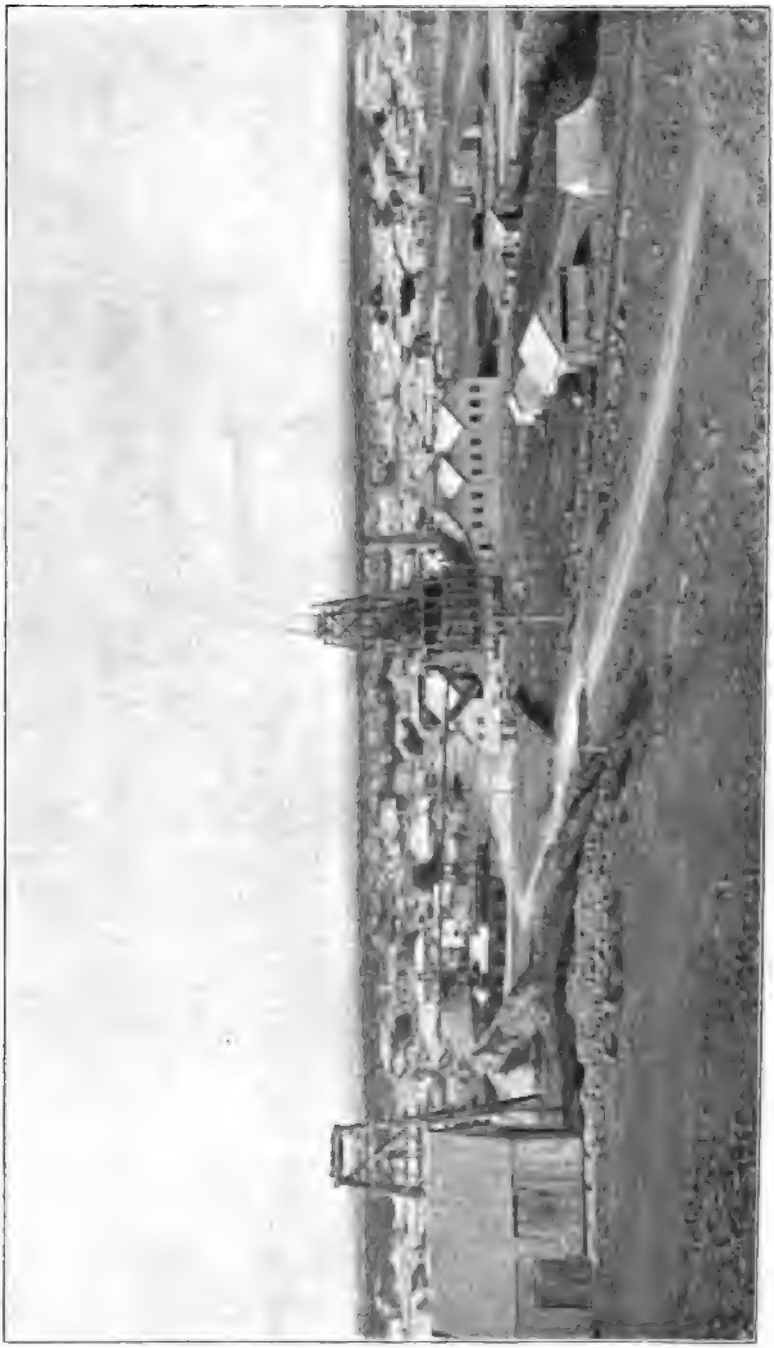


Fig. 1.—View of Charters Towers.

that from 1872 to 1900 (a period of 28 years) the gold-product has reached the by no means despicable total of 5,368,319 ounces valued at £17,500,000.

*Geology.*

The country of the reefs is, for the most part, granitic, being, in fact, a portion of the eastern seaboard range of Australia, raised by the agencies of continental development and denuded until the underlying plutonic rocks have been reached. The greater number of the important reefs—those in the eastern portion of the gold-field—occur in granites; but to the west, some occur in highly metamorphosed sedimentary rocks, which are mainly slates, slaty shales, and quartzites, the former being highly ferruginous. These stratified rocks have a general north-westerly and south-easterly strike, with dips at fairly high angles both to the north-east and south-west. They are overlain unconformably by limestones of Devonian age and are, probably, Upper Silurian. The granites are mainly of the normal type, but in places they shade insensibly into a hornblende-granite, where biotite is almost completely replaced by hornblende. Tonalite (quartz-mica-diorite) is not uncommon on this gold-field.

An inspection of the plan of the gold-field shews the reefs to have no uniformity in strike or in dip. Generally speaking, however, they may be said to be disposed in a rudely semicircular position, with the curve towards the west and the chord running north and south, and to dip towards the centre at varying angles. The angle of dip appears to exercise but little influence on the richness of the reefs, flat and steep reefs being equally productive or non-productive, as the case may be.

In the early days of reefing, when operations were carried on above water-level, the gold was found free in a highly ferruginous quartzose matrix. Below water-level, however, (lying here at a depth of 80 to 100 feet) the iron oxides associated with the gold gave place to pyrites, zinc-blende and galena. The latter is locally considered to be the best indicator for gold, which here, as elsewhere, is not generally disseminated throughout the quartz, but rather runs in shoots in the reefs, often with a regular dip along the course of the reef. The average value of the Charters Towers electrum may be stated at £3 8s. 6d. per ounce.

The Brilliant is the principal reef of the field. On this reef are located the Brilliant and St. George, the Brilliant Central, the Brilliant, the Brilliant Block, the Brilliant Extended, the Brilliant Freeholds, the Brilliant Deep Levels and other mines. The neighbouring reefs include the St. George, Victory, Worcester, Victoria, Caledonia and Queen mines; all of which have been, and are being, worked with handsome returns.

At the western end of the gold-field is another famous reef —the Day Dawn—carrying also its quota of noted dividend-paying mines, of which the more important are the Day Dawn P.C., Mills Day Dawn United, Day Dawn Block and Wyndham, and the Day Dawn Freeholds Consolidated. The last is a block-claim, in which the reef was struck after nearly 2,000 feet of vertical sinking.

The Day Dawn reef is partly connected with the Brilliant system of reefs by the Mexican reef, but between the Day Dawn and the Mexican, and the Mexican and the Brilliant, there exist two, as yet unproductive, belts of country.

*Mining.*

Since the surface of the gold-field is fairly level, or at most, undulating, all winning operations are performed by means of shafts. Early practice favoured the adoption of underlie shafts following the dip of the reef, mainly on account of the ease with which such shafts could be sunk and the knowledge gained of the reef in the course of the operation. Subsequent experience has, however, shown that it is false economy to sink the shaft in the reef, since the expense of constant repairs and renewals more than outweighs the extra initial cost consequent on sinking in solid rock, either vertically to the reef or in the foot-wall. Now the general practice is to sink vertically to a depth of 1,500 or 2,000 feet, until the reef is struck (the upper levels of the Brilliant and Day Dawn Reefs being more or less exhausted), and to continue the shaft as an underlie in the reef. At the Day Dawn Freeholds Consolidated mine, the shaft, which struck the reef at a depth of 1,990 feet, is continued vertically, and crosscuts are driven to the reef at intervals of 100 feet. With a steep reef this is undoubtedly the best practice, but with a reef such as the Brilliant, showing an

average dip of only 30 degrees, the rapidly increasing length of successive crosscuts militates against the adoption of this method.

The better and modern shafts measure 16 feet by 4 feet and 12 feet by 4 feet in the clear, divided into four and three compartments respectively. Many of the older shafts are of very small dimensions compared with their depths, shafts 1,000 feet deep being divided into two compartments each measuring only 3 feet by 3 feet in the clear (Table I.).

TABLE I.—DIMENSIONS OF SHAFTS, ETC.

| Name of Shaft. | Vertical Depth. | Dimensions of Shaft in Clear. | No. of Compartments. | Dimensions of Winding Compartments. |
|---|---|---|---|---|
| | Feet. | Feet. Feet. | | Feet. Feet. |
| Day Dawn Freeholds Consolidated | 2,035 | 15½ by 4 | 4 | 3½ by 4 |
| Brilliant Deep Levels ... ... | 2,556 | 12½ „ 4 | 3 | 4 „ 4 |
| Brilliant Central ... ... | 2,002 | 11 „ 3½ | 3 | 3½ „ 3½ |
| Mills United ... ... ... | 1,214 | 13 „ 4 | 4 | 4 „ 4 |
| Day Dawn Block and Wyndham ... | 540 | 12 „ 4 | 3 | 4 „ 4 |
| New Queen ... ... ... | 1,717 | 16 „ 4 | 4 | 4 „ 4 |
| Brilliant and St. George ... | 1,093 | 10 „ 6 / 12 „ 8 | 3 | — |
| Band of Hope ... ... ... | 980 | 6 „ 3 | 2 | 3 „ 3 |
| Clark's Brilliant, Worcester and Victory ... ... ... | 642 | 8 „ 4 | 2 | 4 „ 4 |

TABLE I.—*Continued.*

| Name of Shaft. | Sizes of Lining and Centreing. | Sizes of Guides. | Method of Sinking | Average Rate of Sinking per Month. | Average cost per Foot. |
|---|---|---|---|---|---|
| | Ins. Ins. | Ins. Ins. | | Feet. | £ s. d. |
| Day Dawn Freeholds Consolidated ... | 8 by 2½ / 8 „ 3 | 6 by 3 | Machine | 94 | 8 0 0 |
| Brilliant Deep Levels ... | 8 „ 2½ | None | do. | 88½ | — |
| Brilliant Central ... ... | 8 „ 2 | 4 by 3 | do. | 72 | — |
| Mills United ... ... | 8 „ 2½ | 4 „ 3 | do. | - | — |
| Day Dawn Block and Wyndham ... ... ... | 8 „ 2 | 4 „ 3 | do. | — | — |
| New Queen ... ... | 8 „ 2 | 4 „ 4 | do. | — | — |
| Brilliant and St. George ... | 8 „ 2 | 4 „ 3 | do. | 79 | 10 0 0 |
| Band of Hope ... ... | 8 „ 2 | 4 „ 3 | Hand | 40 | 5 0 0 |
| Clark's Brilliant, Worcester and Victory ... ... | 8 „ 2 | 4 „ 3 | Machine | 70 | 4 10 0 |

*Sinking.*—The sinking of the shafts is in the larger mines effected with the aid of machine-drills, the Ingersoll-Sergeant being the favourite type. The procedure in sinking the shaft of the Day Dawn Freeholds Consolidated mine may be taken as typical of the best practice in granite-country. This shaft is

15½ feet by 4 feet in the clear, the excavation in the granite being roughly 18 feet by 6½ feet. Four Ingersoll-Sergeant machines, carrying 1¼ inches steel-drills, were used, two machines being clamped on each of two stretcher-bars disposed horizontally across the shaft. In each "sink," 32 to 36 holes were bored. The eight "centre-cut" holes were about 7 feet deep and were disposed in pairs, each pair being inclined to meet at their extreme depth. The rear rows of holes were successively given less inclination, so that the outside rows were even inclined slightly outward. Actual drilling occupied 4½ hours, the remainder of the shift of 8 hours being occupied in rigging the machines. The two succeeding shifts were fully employed in charging and firing the holes, and clearing away the resultant débris. The holes were charged with blasting-gelatine, and fired by a magneto-electric machine. The average rate of progress was 5 feet 8½ inches per complete "round" or "sink," and the record progress in sinking this shaft (a record also claimed to be Australian) was 137 feet per month of 24 days (Sunday labour is non-existent at Charters Towers). The average progress for the whole depth of the shaft (2,035 feet) was 94 feet per month. The débris were raised the whole distance to the surface by kibbles or buckets.

*Timbering.*—For shafts, the system adopted is very simple, and at the same time perfectly adequate. The shaft is merely close-lined with planks, 8 to 9 inches deep and 2 to 3 inches thick, set on edge. The centreing is generally planking of the same depth and thickness as the wall-plates and end-plates, into which it is checked. Bearers or frame-sets are hitched into the rock at distances varying from 60 to 80 feet, according to the nature of the ground. Great care is taken in packing, behind the lining, with rock, and in bringing each set to truth, with plumb-line and level. In these dry regions, water occasions but little trouble in sinking, and may generally be kept under by an hour's baling per shift with the water-bucket. Small prospecting-shafts are often cribbed with round timber, 4 to 6 inches in diameter. So far as the writer is aware, no shafts now exist with frame-sets, studdles and lagging. Guides are made of hard wood (4 inches by 3 inches), occasionally faced with sheet-iron. In the new shafts, however, a guide, 6 inches by 3 inches,

is being adopted, thus enabling the line of coach-screws, by which the guides are fastened to the lining, to be broken.

Underlie shafts are timbered in the same way as drives or levels, except that sole-pieces are added to form sleepers for the skip-rails. At the Day Dawn Block and Wyndham and also at the Mills Day Dawn United mines, the underlie shaft is kept open by a system of square cribs, or "pig-sties," as they are locally termed. These cribs are 6 feet square, formed of round timbers, 6 to 8 inches in diameter, laid two and two crosswise, and are built up to the hanging-wall at right angles to the dip. There may be a single or a double row of cribs on each side of the underlie. The cap-pieces, which stretch across the shaft from crib to crib, may be 12 to 20 inches in diameter. The cribs are packed with waste-rock and wedged with saplings. Occasionally a single "tom" or post, reaching from wall to wall, is placed in the centre of the crib before packing, permitting by its slow crushing the superincumbent weight to come gradually on the crib.

Speaking generally, the granite of the gold-field forms good "standing-ground" and many levels are driven for the whole of their length without timbering. Often a mere "reacher" or "tom" suffices to render the drive safe. With the progress of stoping operations, however, more is necessary, and the drive is secured by two props, a cap-piece, and the necessary lagging or "lacing." Where the primitive and objectionable practice of merely notching the top of the prop and laying the cap in the V shaped seat so formed, does not obtain, the "clap-me-down" or "slap-me-down" joggle is ordinarily used.

*Workings.*—The levels are generally driven along the hanging-wall of the reef, if the latter be small; or in the reefs, if it be of sufficient size. In the best practice, the levels are always driven by machine-drills. The following progress in a cross-cut, 11 feet by 8 feet, at the Brilliant Central mine in hard granite, may be noted. A distance of 198 feet was driven by 4 men per shift, in 6 weeks of 18 shifts per week, with two machines. The best work for a fortnight was 73 feet. No timbering was necessary.

*Stoping.*—Overhand stoping is everywhere adopted, recourse

being had to underhand stoping only when it is necessary to take out rich quartz as quickly as possible. The passes or ore-chutes are cribbed, and are generally placed 30 to 40 feet apart, or at such distances as may be rendered necessary by the width of the reef. With narrow reefs, the distance is considerably reduced. In very flat reefs, such as the Brilliant, it is, unfortunately, necessary to shovel the quartz four or five times or even more, before reaching the chute-doors, thus adding quite 1s. to 1s. 6d. per ton to working expenses. In stoping operations, machine-drills are gradually replacing hand-drills; but as yet half-measures only are adopted, since the same heavy drills that are used in the levels below are also used in the stopes. These heavy drills will no doubt before long be superseded by suitable stoping-drills weighing only 150 pounds, with a $2\frac{1}{4}$ inches instead of a $3\frac{1}{2}$ inches cylinder, and carrying $\frac{7}{8}$ inch instead of $1\frac{1}{2}$ inches steel-drills.

After stoping, the hanging-wall is variously supported. With a treacherous flaking hanging-wall as in the Day Dawn reef, working-room only can be left between the packing below and the reef above, and even then toms or stulls must be extensively employed. In working on the Brilliant reef, however, with a good hanging-wall, large open spaces may be left, and the hanging-wall is supported only here and there by pig-sties or cribs. In most of the mines on this gold-field, sufficient waste is obtained in the ordinary operations of mining to fill the stopes. In the Brilliant and St. George mine, for many years past the premier mine of the gold-field, it has recently been found necessary to send down filling material from the surface.

*Breaking Ground.*—The procedure in excavating shafts and drives with machine-drills has already been described. In small mines, however, hand-drills are exclusively used in similar work. In this case, $\frac{5}{8}$ to $\frac{7}{8}$ inch octagonal steel is used and the miners work single-handed. Where machine-drills are employed, tripods are seldom used, the machine being rigged on columns or stretchers. Compressed air is invariably the motive power, with an average pressure at the drills of 75 to 80 pounds per square inch. At Charters Towers, the reprehensible practice of boring dry holes obtains, to the detriment of the tool and to the

discomfort of the drillmen. Chisel-bits are invariably used, and nowhere on this field has the writer seen +, Z, or S bits in actual use. This arises probably from the difficulty in sharpening the latter forms.

Four grades only of explosives are used: for shaft-sinking or for tight ground, blasting-gelatine; and for all other ordinary operations, gelatine-dynamite, gelignite and a little dynamite. All grades are, however, known to the miner as "fracture" (a contraction of lithofracteur, which has been discarded for many years).

*Winding Appliances.*—Windlasses, whips, and whims have long been relegated to outlying gold-fields, their places being taken in the deeper mines by modern winding-machinery. The Day Dawn Freeholds Consolidated mine is winding at present from a depth of 2,035 feet with a double-drum, double-cylinder, and direct-acting (first-motion) engine. It is, of course, non-condensing, and is fitted with both steam and hand reversing-gear and both band and post-brakes, actuated by foot or by steam. The cylinders are 24 inches in diameter by 4 feet stroke, and the minimum diameter of the drums is 9 feet (Table II.).

TABLE II.—WINDING AND HAULING ARRANGEMENTS.

| Name of Mine. | Height of Head-gear. | Diam. of Pulleys. | Diam. of Drum. | Diam. of Rope. | Capacity of Trucks. | Gauge of Rails. | Weight of Rails per Foot. |
|---|---|---|---|---|---|---|---|
| | Feet. | Feet. | Feet. | Inches. | Cwts. | Inches. | Pounds. |
| Day Dawn Freeholds Consolidated ... | 75 | 7 | 9 | 1 | 20 | 22 | 6 |
| Brilliant Deep Levels ... | 78 | 7 | 7 | 1¼ | — | 22 | 4 |
| Brilliant Central ... | 79 | 8 | 8 | 1 | 15 | 24 | 5 & 11 |
| Mills Day Dawn United | 96 | 6 | 6 & 8 | 1 | 14 | 20 & 30 | 5 & 15 |
| Day Dawn Block and Wyndham... ... | — | 8 | 8 | 1 | 15 | 20 | 5 |
| New Queen ... ... | 75 | 6 | 8 | 1 | 13 | 22 | 5 |
| Brilliant and St. George | 60 | 8 | 8 | 1 & 1¼ | 16 | 19 | 5 & 15 |
| Band of Hope .. ... | 56 | 6½ | 6 | ¾ | 10 | 20 & 30 | 5 |
| Clark's Brilliant, Worcester and Victory ... | 70 | 6 | 6 | ⅝ | 14 | 20 & 30 | 6 |

Auxiliary underground winding is effected by compressed-air engines, which have completely supplanted steam-engines for this work. Wood is the only fuel used in the Charters Towers field, costing on an average 18s. 6d. to 20s. per cord, and it is of good quality.

At all mines, round steel winding-ropes are used, varying in diameter from ⅞ inch to 1½ inches. They are generally of six strands with 12 to 19 wires to the strand, and are all of the Lang lay type. The life of ropes in vertical shafts is much longer than in moister climates, a good rope usually lasting for 5 years.

As previously remarked, all sinking is performed with buckets or kibbles, which are generally discarded, when sinking is completed, in favour of safety-cages, fitted with overwinding hooks. In some cases, however, the bucket is retained, in defiance of modern experience on the subject. Near a shaft fitted with the most improved winding-appliances may be seen another in which men and quartz are raised from a depth of 2,556 feet in a bucket—and that without a swivel at the bucket-head. This of course is rendered possible by the system of timbering, which presents no protruding surfaces on which a bucket may catch.

Skips are but little used, the preference being given to cages and trucks. All cages are single-decked.

*Headgear.*—The form of the poppet-heads or headgear, varies little. Four round poles are placed at the four corners of a square (at the intersection of the diagonals of which is the shaft) and are inclined inwards, meeting at a platform directly over the shaft. The structure is braced, and a plank platform placed at a convenient height to serve as a brace. The poppet-heads of the Mills Day Dawn United mine (Fig. 2) are 96 feet high. The four poles of which it is composed are of New Zealand kauri pine, and are each 105 feet long and 24 inches in diameter at the bottom. The pulleys used are, as a rule, too small, the largest on the gold-field being only 9 feet in diameter (Table II.).

*Pumping.*—As might be expected in so dry a region, the unwatering of a mine presents but little difficulty to the Charters Towers mine-manager. The method generally adopted in straight shafts is simple and efficacious. Water-tanks are used which are automatically filled and emptied in the sump and at the surface respectively. Underlie shafts are unwatered by high-pressure force pumps of the Knowles, Blake or Worthing-

FIG. 2.—VIEW OF HEADGEAR OF MILL'S DAY DAWN UNITED MINE.

ton types, which pump the water to the sump in the vertical shaft, where the water-tank takes up the duty. It is extremely improbable, moreover, that mine-drainage will ever be a problem to be seriously faced, for it is unlikely that more water will be met with at a depth of 3,500 or 4,000 feet than is now encountered at 2,500 feet.

*Ventilation.*—The summer shade temperature of Charters Towers ranges from 90° to 110° Fahr. When it is remembered that the smaller mines are entirely dependent on natural ventilation, some conception may be formed of the conditions under which many of the miners work. In a stope, where the vitiated air, after traversing several working-places, may have attained a temperature of 115° to 120° Fahr., clothes are a superfluity, and the miners necessarily work stripped to the waist. In the larger mines, with several openings to the surface, the ventilation is usually efficient, and especially is this the case where machine-drills, worked by compressed air, are used. Not only is the air actually delivered to the working-face, but the expansion of the air on liberation absorbs a considerable amount of heat, perceptibly cooling the workings. At the Day Dawn Freeholds Consolidated mine special provision is made for the ventilation of the working stopes by the use of a system of piping (½ inch) connected with the compressed-air mains and terminating in nozzles beside the workmen.

TABLE III.—COST OF RAISING QUARTZ AT THE BRILLIANT AND ST. GEORGE MINE.

| | Total Amount. | | | Cost per ton. s. | d. |
|---|---|---|---|---|---|
| Wages ... ... ... | £12,699 | 19 | 3 | 13 | 11·068 |
| Stores ... ... ... | 1,265 | 8 | 5 | 1 | 4·647 |
| Firewood ... ... | 1,129 | 5 | 1 | 1 | 2·860 |
| Timber ... ... ... | 496 | 7 | 9 | 0 | 6·530 |
| Repairs ... | 120 | 4 | 9 | 0 | 1·581 |
| Coal and charcoal .. | 25 | 14 | 0 | 0 | 0·338 |
| Insurance of workmen ... | 142 | 2 | 0 | 0 | 1·869 |
| Totals | £15,879 | 1 | 3 | 17 | 4·893 |

*Costs.*—Few mines are raising quartz so regularly that the costs may justly be apportioned at so much per ton raised. The costs at the Brilliant and St. George mine for the half-year ending August 15th, 1900, during which 18,244 tons were raised and crushed, are recorded in Table III.

### *Milling.*

Water, the dominant factor in North Queensland life, also exercises its influence on the location of the mills. While the mine may be situated anywhere on the field, the mill must be located close to water or, at any rate, close to a spot where facilities exist for impounding water. Hence the Brilliant and St. George mill is 1½ miles distant from the mine, and the Day Dawn Block and Wyndham mill is located on the bank of the Burdekin river, no less than 11 miles away from the mine. Carriage is effected in the former case by waggon, and in the latter by the Government railway.

The majority of the crushing-mills of Charters Towers were erected many years ago, before the metallurgy of gold became an exact science, and consequently show but little regard for economy in the handling of quartz. The Burdekin and the Brilliant and St. George mills are located on slopes which give ample room for gravitational treatment. At the Brilliant Block mill, of 40 stamps, the rock-breaker is placed on the floor and the crushed ore is raised by conveyors to the ore-bins above the stamps. The older mills, many of which are customs mills, are one by one remedying the defects of early construction by the adoption of a similar system. The breakers in general use are the Blake, Blake-Marsden, Hope and Dodge machines. From the breakers the crushed ore is conveyed to the ore-bin shute by bucket-conveyors and carried to the necessary bin by a horizontal endless scraper-belt working in the shute. A much more complicated method of effecting the same result is shortly to be put into practice at the Defiance mill. This is a customs mill, crushing for the public. It is, therefore, often necessary to treat small parcels and to keep them separate. Six rock- (uncrushed quartz) bins are provided, corresponding with six ore-bins above the stamps. Below the rock-bin shutes is a railway-track along which a large Blake-Marsden crusher may be moved. Attached to the boot of the breaker and moving with it is a bucket-conveyor, the head of which runs on a single rail over the ore-bins. The quartz from any rock-bin may therefore be passed through the crusher, and elevated to the corresponding ore-bin, which in its turn is connected with a separate battery of 5 stamps. At the Bonnie Dundee mill of only 20 stamps, where hand-feeding and spalling is still adhered to, 3 feeders

FIG. 3.—VIEW OF HEADGEAR OF BRILLIANT MINE.

and 2 spallers are employed at a total cost of £2 10s. per shift or £180 per month. No very abstruse calculation is required to show that in a very few months the total cost of an installation of rockbreakers, conveyors and ore-bins would be recouped from the saving in wages alone.

*Battery.*—The battery standards are invariably of iron, and are generally cast hollow. Wood is in all parts of Queensland subject to the ravages of the white ant. For the same reason the guides are of iron, without bushing either of wood or of metal. In the older mills all cams are placed on one main cam-shaft, but in recently erected crushing-plants, each battery of 5 heads has its separate cam-shaft and driving-pulley. Owing, as will be explained, to the form of the tappet, the cams are generally all right-handed. The cams are of the ordinary type and are fastened to the shaft by two keys, keyseats and keyways. Little attention is paid in Charters Towers mills to the throw of the stamp in its revolution. With new cams and tappets this is not a difficult matter to control, and due attention to this important details ensures the even wear of shoe and die.

TABLE IV.—MILLING PRACTICE.

| Name of Mill. | No. of Stamps. | Weight of each Stamp. | No. of Blows per Minute. | Height of Drop. | Depth of Discharge. | Life of Screens. | Capacity of each Stamp *per diem*. | Capacity of whole Mill *per diem*. |
|---|---|---|---|---|---|---|---|---|
| | | Pounds. | | Inches. | Inches. | | Tons. | Tons. |
| Bonnie Dundee | 20 | 800 | 74 | 9 to 10 | 1½ to 5½ | Average, 3 days. | 2·6 | 653 |
| Brilliant Block | 40 | 900 | 75 | 9 to 10 | 0 to 4 | | 2·6 | 110 |
| Enterprise ... | 10 | 1,100 | 90 | 8½ | ... | | 2·2 | 22 |
| Defiance ... | 30 | 1,050 | 76 | 7 | 1½ to 5½ | | 2·4 | 75 |
| Rainbow .. | 15 | 1,100 | 85 | 9 | 2 to 8 | | 2·3 | 35 |
| Venus ... .. | 30 | 900 | 70 | 8 | 1 to 4½ | | 2·7 | 84 |
| Burdekin ... | 60 | 900 | 75 | 8 | {1 to 5½, 6 to 10} | | 2·0 | 125 |

In the majority of mills, the stamps drop in the order of Nos. 1, 5, 2, 4 and 3. In one or two, the order Nos. 1, 5, 3, 4 and 2 is adopted. Again the practice of dropping the stamps in pairs may be met with. Nos. 1 and 5, and Nos. 2 and 4 being thus dropped, followed by No. 3. The advantages of the last method are hard to discover. The splash is not improved, and a considerable strain is imposed on the cam-shaft and on the teeth of the spur-wheels, where the latter are used (Table IV.).

The primitive form of tappet or disc, consisting simply of an iron collar wedged into place by a vertical iron key driven between the stamp-stem and the collar from above, may yet be met with on this gold-field. The two-way and three-way Californian tappet is found in one or two mills, but the great majority use a screw tappet, halved vertically, and secured by two pairs of bolts passing through lugs. A round thread of $\frac{3}{4}$ pitch is cast on to the tappet. This form is, unlike the V thread tappets, not liable to be stripped, and has a great advantage in the ease with which it may be moved up and down the shank, in this respect showing a decided superiority over the American type. The tappet is furnished with a false wearing-face, held in place by countersunk vertical bolts. The disadvantages of the type are that neither the shank (stamp-stem) nor the tappet can be reversed, and that the cam must be used only on one side of the shank, so that (in the event of the cross-bolts loosening) the tappet may be turned up the shank until out of action.

The stamp-stems are from 11 to 14 feet long and $3\frac{1}{4}$ to $3\frac{1}{2}$ inches in diameter, and are fitted to the heads in the ordinary manner. The heads and shoes are cylindrical, varying from 8 to 10 inches in diameter. The shoe is generally made of hæmatite-iron. The dies are always octagonal, $8\frac{1}{2}$ to $10\frac{1}{2}$ inches across and $5\frac{1}{2}$ inches deep.

The weights of an average 950 pounds stamp are distributed much as follows:—Shank, 336 pounds; head, 256 pounds; shoe, 240 pounds; tappet, 112 pounds: making a total of 944 pounds. The corresponding die will weigh 224 pounds.

The mortar-box is rectangular in shape, adapted for inside amalgamation, and weighs, with liners, about $2\frac{1}{2}$ tons. The front is broken into two screen-areas, a practice little to be commended. One type and form of screen is everywhere used. This is of charcoal-iron, burr-punched, with 224 holes of No. 6 needle size (0·027 inch) to the square inch. In the Burdekin (Day Dawn Block and Wyndham) mill a wire-woven screen is being tentatively used. This is of No. 15 size with steel wire of No. 23 Birmingham wire-gauge (0·025 inch). The burr-punched screen (even with all the burr worn off) gives an effective discharge-area of only 16·4 square inches per square foot, while the wire-woven screen gives 43·2 square inches per square foot.

All screens are set vertically, in defiance of modern experience, which shows that discharge is considerably facilitated by a forward inclination of 8 to 10 degrees.

No attempt is made to regulate the depth of discharge, which may vary from 2 to 10 inches, and to this fact may be attributed much of the difficulty with slimes, at present confronting the Charters Towers millman and cyanider.

*Huntington Mills.*—At the Brilliant and St. George mill are installed six 5 feet Huntington mills, each of a capacity of 20 tons per week, which on Charters Towers quartz, is equal to a battery of 8 heads of the local type. These mills are working on fairly hard quartz, and are driven at a speed of 65 revolutions per minute. Though they have many minor advantages and notwithstanding the fact that, mainly owing to the care, skill and long experience of the mill-manager, they are doing excellent work at the above plant; the writer has no hesitation in affirming his opinion that for crushing hard stone like that of the gold-field under discussion, they are inferior to the modern stamp-mill. This opinion is fortified by a comparison made in Table V. of the working costs of the above mill with that of the Brilliant Block mill of 40 stamps. Both mills are crushing stone from the same reef, and the comparison is made for approximately the same half-year, when all costs of labour, fuel, etc., are identical, and, moreover, the tonnage crushed by each mill is sufficiently alike for purposes of comparison. The Brilliant Block mill for the half year ending July 24th, 1900, crushed 14,708 tons, and the Brilliant and St. George for a similar period ending August 15th, 1900, crushed 18,072 tons. Carriage must be deducted from the total costs of both, since the Brilliant and St. George mill is 1 mile farther away from the mine than the Brilliant Block from its mine. The wear-and-tear on the Huntington battery will be seen to represent a considerable sum, and that this is no isolated half-year in which extraordinary repairs were effected, will be gathered from the fact that renewals and repairs for the two previous half-years were £3,161 2s. 4d. and £2,232 14s. 7d. respectively.

The net cost, therefore, shows a balance of, roughly, 2s. per ton in favour of stamp-mills, a sum which the writer is confident could be increased by attention to stamping details.

*Amalgamation.*—Inside amalgamation, in so far as it consists in the introduction of mercury into the mortar-box, is practised, but neither inside amalgamated plates nor inside mercury-riffles are used. For reasons which cannot be discussed within the limits of this paper, inside amalgamation is not to be recommended for Charters Towers stone. Outside the

TABLE V.—COSTS OF MILLING AT THE BRILLIANT BLOCK AND THE BRILLIANT AND ST. GEORGE MILLS.

| | Brilliant Block Mill (14,078 tons crushed). | | Brilliant and St. George Mill (18,072 tons crushed). | |
|---|---|---|---|---|
| | Total Amount. | Cost per ton. | Total Amount. | Cost per ton. |
| | £ s. d. | s. d. | £ s. d. | s. d. |
| Wages ... ... ... | 2,303 10 4 | 3 1·59 | 3,023 2 0 | 3 4·14 |
| Firewood ... ... ... | 1,621 8 11 | 2 2·46 | 1,853 3 8 | 2 0·61 |
| Renewals and repairs ... | 1,083 18 6 | 1 5·69 | 2,263 5 0 | 2 6·05 |
| Stores ... ... ... | 336 11 0 | 0 5·49 | 1,159 0 10 | 1 3·39 |
| Carting quartz ... ... | 270 11 4 | 0 4·41 | 1,182 11 3 | 1 3·71 |
| Water ... ... .. | 49 10 0 | 0 0·80 | — | — |
| Coal and charcoal ... | 16 11 1 | 0 0·27 | 10 18 7 | 0 0·14 |
| Sundries ... ... ... | 10 14 3 | 0 0·17 | 32 9 0 | 0 0·43 |
| Timber ... ... ... | 11 1 9 | 0 0·18 | — | — |
| Salaries ... ... ... | — | — | 26 0 0 | 0 0·34 |
| Insurance of workmen ... | — | | 85 19 8 | 0 1·16 |
| Totals ... ... ... | 5,703 17 2 | 7 9·06 | 9,636 10 0 | 10 7·97 |
| Less carting ... ... | 270 11 4 | 0 4·41 | 1,182 11 3 | 1 3·71 |
| Net costs ... ... ... | 5,433 5 10 | 7 4·65 | 8,453 18 9 | 9 4·26 |

TABLE VI.—AMALGAM-RECOVERY FROM THE SAVING APPLIANCES OF AN AVERAGE MILL.

| Name of Mill. | Total Quantity of Amalgam. | Mortar-boxes. | Mercury-wells. | Copper-plates. | Wheeler-pans. | Berdans. | Skims. | Sundries. | Retort Percentage. |
|---|---|---|---|---|---|---|---|---|---|
| | Ounces. | per cent | per cent. | per cent. | per cent. | per cent. | per cent. | per cent. | |
| Brilliant Block ... | 35,017 | 23·90 | 4·7 | 33·03 | 13·0 | 8·9 | 9·1 | 6·91 | 40·9 |
| Bonnie Dundee ... | 2,220 | 8·0 | 31·7 | 23·97 | 25·5 | 7·5 | 3·4 | — | 30·6 |

battery, a number of short plates, from 14 to 27 inches long, with intermediate riffles and mercury-wells, are employed. The slope of the tables varies from $\frac{3}{4}$ to $1\frac{1}{8}$ inches per foot and this inclination is never varied when once set. Plain copper-plates are in general use. The average loss of quicksilver appears to

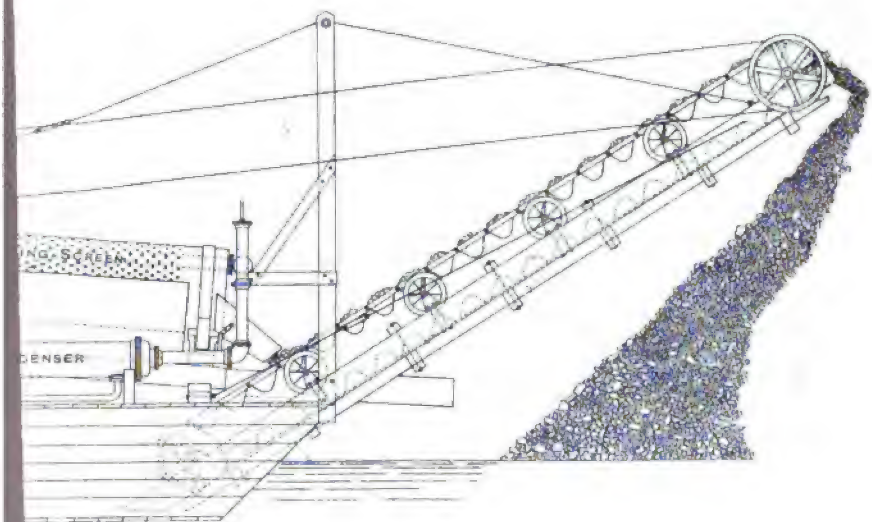
be about 4 to 6 pennyweights per ton of ore crushed. Table VI. shews the recovery from the different saving appliances of an average mill.

*Concentration.*—Rough concentration is effected in ripples, about 2 inches wide and ¾ inch deep, and set between successive copper-plates on the same table.

These ripples are cleaned by suitably shaped scoops as often as may be necessary. The favourite concentrator, however, on the Charters Towers gold-field is the Brown-Stanfield, a modification of the old Hendy concentrator, and a form that has been in use on the gold-field since its opening. They are good, coarse concentrators (when not overloaded), but are not to be compared with modern concentrators of the Wilfley type. Moreover, as the general tendency is to overload, the product is not by any means a clean concentrate. The round, concave buddle is also attached to a few of the older mills and has done good work in the past. At the Burdekin mill, 20 Frue-vanners were installed some years ago, but failed to give satisfaction and were discarded. The reason for this retrograde step will be clear, when it is stated that the management of these vanners was entrusted to men who had little or no previous experience of their working.

The general method of after-treatment of the concentrates from the Brown-Stanfield machines and from the ripples is to grind with mercury in Berdan or Wheeler pans. The former pan is the favourite, and a recent return shews that on this gold-field alone there are no less than 468 Berdan pans together with 96 Wheeler and other pans. Continuous grinding is the rule, and in no case are concentrates treated in charges. The inevitable result is the formation of the maximum quantity of slimes and the loss of the maximum quantity of "sickened" mercury.

*Cyanidation.*—The sands, slimes and sludges—the battery-residues, as distinguished from the concentrates—are passed over to the cyanider. Chemically speaking, there is but little difficulty in treating these sands, since copper-pyrites is rarely present. This is well illustrated by the fact that the potassium-cyanide process was introduced into Charters Towers by



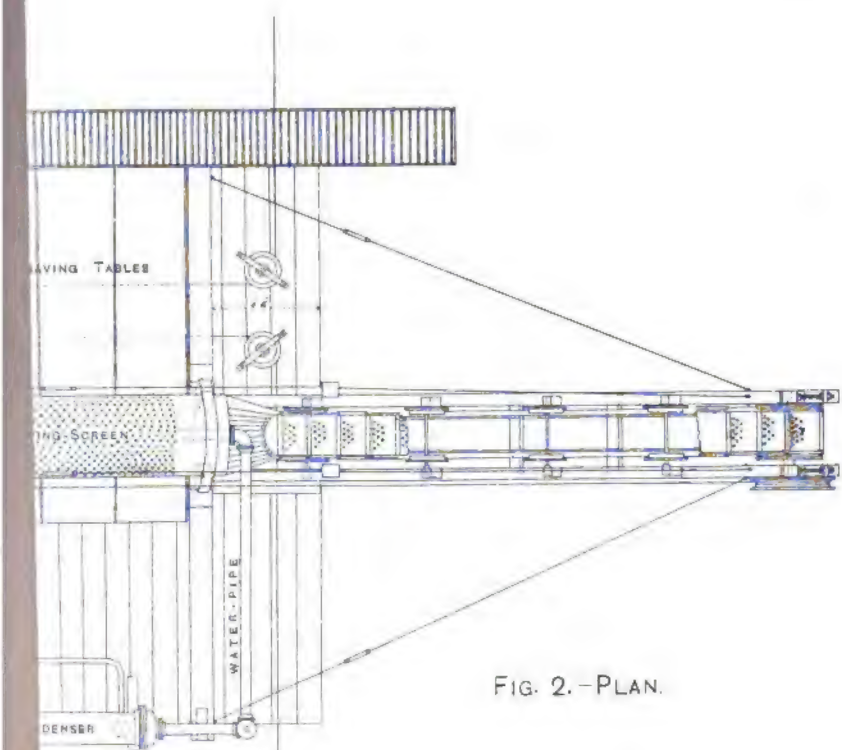




FIG. 2.—PLAN.

labourers and miners, who were absolutely devoid of all chemical knowledge and worked entirely by empirical rules. The fact that it has paid in some cases to treat these sands three times over by cyanide-solution, throws a curious light on the methods of the early cyaniders, and, *inter alia*, on the gold-saving capacities of the mills through which the sands or tailings passed. Fig. 4 shews one of the early cyanide-plants.

The great difficulty of the cyanider is therefore mechanical, and is the difficulty of percolation due to the large proportion of slimes. The residues from the crushing-mills are run into pits, and when in sufficient quantity, are sold by auction to the owners of the cyanide-plants, who spread their purchase to be dried by the heat of the sun—neither a difficult nor a protracted matter in Charters Towers—and pass the dried lumps through a disintegrator. Care is taken to regulate the proportion of slimes to sands: 1 ton of the former being generally mixed with 2 or 3 tons of the latter, in order to ensure percolation. Where sands are not procurable in sufficient quantity from the mills, spent sands that have already been treated by cyanide-solutions are used to mix with the slimes, and when it is remembered that the latter may be worth as much as £3 3s. per ton, it will be seen that there is yet left a large margin for profit.

TABLE VII.—COST OF POTASSIUM-CYANIDE PROCESS.

| | Brilliant and St. George Mill—18,600 tons treated. | | | | | Brilliant Block Mill—15,272 tons treated. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total Amount. | | | Cost per ton. | | Total Amount. | | | Cost per ton. | |
| | £ | s. | d. | s. | d. | £ | s. | d. | s. | d. |
| Cartage from pits ... ... | 809 | 12 | 11 | 0 | 10·45 | 598 | 1 | 10 | 0 | 9·39 |
| Wages ... ... ... | 799 | 12 | 6 | 0 | 10·31 | 2,316 | 14 | 0 | 3 | 0·40 |
| Emptying vats ... ... | 391 | 0 | 0 | 0 | 5·04 | — | | | — | |
| Carting to hoppers ... | 546 | 0 | 0 | 0 | 7·04 | — | | | — | |
| Stores ... .. .. | 302 | 18 | 3 | 0 | 3·91 | 148 | 13 | 10 | 0 | 2·33 |
| Potassium cyanide ... | 2,160 | 0 | 8 | 2 | 3·90 | 952 | 0 | 0 | 1 | 2·96 |
| Coal and coke ... .. | 123 | 11 | 8 | 0 | 1·60 | 25 | 9 | 8 | 0 | 0·40 |
| Lime ... ... ... | 63 | 16 | 1 | 0 | 0·82 | 136 | 18 | 10 | 0 | 2·15 |
| Royalties ... ... .. | 1,081 | 15 | 6 | 1 | 1·96 | 244 | 10 | 6 | 0 | 3·84 |
| Renewals and repairs .. | 72 | 9 | 5 | 0 | 0·93 | 326 | 19 | 10 | 0 | 5·14 |
| Firewood ... .. ... | 132 | 17 | 5 | 0 | 1·71 | — | | | — | |
| Storage and cartage of sand | 59 | 0 | 0 | 0 | 0·76 | — | | | — | |
| Zinc discs ... ... | 94 | 3 | 6 | 0 | 1·21 | — | | | — | |
| General expenses ... ... | 39 | 9 | 6 | 0 | 0·51 | 2 | 10 | 7 | 0 | 0·04 |
| Totals ... £ | 6,676 | 7 | 5 | 7 | 2·15 | 4,751 | 19 | 1 | 6 | 2·65 |

The cost of ordinary cyaniding at Charters Towers may be said to average about 7s. 6d. per ton. Table VII. contains costs from the two principal cyanide-mills on the field.

*Wages and Materials.*—The current rates of wages and prices of material are recorded in Tables VIII. and IX.

TABLE VIII.—RATES OF WAGES.

| Class of Labour. | Wages per week. £ s. d. | Class of Labour. | Wages per week. £ s. d. |
|---|---|---|---|
| Mine-managers ... ... | 5 0 0 to 10 0 0 | Mill-managers ... .. | 6 0 0 to 8 0 0 |
| Mechanics ... ... .. | 4 5 0 | Assayers ... ... ... | 5 0 0 |
| Carpenters, smiths, and engine-drivers ... ... | 3 10 0 | Cyanide-superintendents ... | 5 0 0 |
| | | Amalgamators ... .. | 4 0 0 |
| Shift-bosses... ... ... | 4 0 0 | Feeders ... ... ... | 3 0 0 |
| Pitmen and drillmen ... | 3 5 0 | Cyanide-labourers ... ... | 2 8 0 |
| Miners, timbermen, bracemen, and labourers ... | 3 0 0 | Blanket-boys ... ... | 1 10 0 to 2 10 0 |
| Truckers ... ... ... | 2 10 0 | | |

TABLE IX.—COSTS OF MATERIAL.

| | s. d. | | s. d. | | s. d. |
|---|---|---|---|---|---|
| Coal per ton ... | 25 0 | to | 40 0 | Detonators per 1000 ... ... | 35 0 |
| Wood per cord ... | 18 6 | to | 20 0 | Drill-steel per pound ... ... | 0 4½ |
| Candles per pound ... ... | | | 0 6¾ | Quicksilver ,, .. .. | 2 10½ |
| Blasting-gelatine per case ... | | | 90 0 | Potassium cyanide per pound ... | 1 1 |
| Gelignite per case | 60 0 | to | 65 0 | Zinc per pound ... ... ... | 0 5½ |
| Fuse per coil ... ... ... | | | 0 8 | Lime per ton ... ... .. | 25 0 |

*Conclusion.*—In general, it may be stated that with Charters Towers mining practice, there is little fault to be found. The same, unfortunately, cannot be said of the milling practice, which has remained stationary for twenty years. And, paradoxical as it may seem, the reason for this stagnation lies in the uniform richness of the reefs. From an inspection of departmental returns for many years past, it would appear that the average gold-content of the quartz crushed has been 31 pennyweights per ton. Therefore, when the stone has been worth crushing at all, it has paid handsomely, and in the general absence of assayers until the last five years, there was perhaps little to show that 40 per cent. of the bullion-content was being lost. No further comment on this subject is necessary after stating the fact that 922,278 ounces of the approximate value of

£2,000,000 sterling, have been recovered since 1894, mainly from the old mill-residues by cyanidation.

Wealthy and prosperous as the gold-field is, it is but little known to the British investor. The local capitalists, who are wanting neither in numbers nor in wealth, are keen business men, not afraid to spend gold and energy in the development of promising mines. And that their enterprise is not unrewarded will be patent from the fact that the dividends paid on the gold-field during the last twelve years amount to £3,285,957. During the year 1900, £299,205 18s. 0d. was paid as dividends on a share market-valuation of approximately £2,015,000, or at the rate of 15 per cent. per annum. The famous Mount Morgan mine, which, after all, must be considered an industrial rather than a mining property, pays 7 per cent.; while the much vaunted Kalgoorlie field in Western Australia, shows a return of only 2½ to 3 per cent. on the market-valuation of the mines.

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The CHAIRMAN (Mr. H. C. Peake) moved a vote of thanks to Mr. Maclaren for his interesting paper. Members were much indebted to colonial members for valuable papers.

Mr. J. S. DIXON seconded the resolution, which was cordially approved.

# USE OF WASTE-GASES FROM BYE-PRODUCT COKE-OVENS IN EXPLOSION-MOTORS.*

By E. REUMAUX, Managing Director, Société des Mines des Lens.†

The following paper gives a brief account of the results obtained at the Lens collieries since the end of 1898 by the employment in explosion-motors of the available excess-gas from bye-product coke-ovens.

*Introduction.*—Mr. Carvès' methods and appliances for the extraction of some of the useful products contained in the gases produced by the distillation of coal in coke-ovens have only made their way slowly into practice. The initiative of the inventor was opposed by the resistance of manufacturers, who were convinced that the quality of the coke was unfavourably influenced by the utilization of the waste-gases. His perseverance and that of Messrs. Otto and Solvay have finally triumphed over these prejudices, and brought manufacturers to recognize that everything else being equal, namely, character of the coal, fineness of crushing, previous compression, etc., the quality of the coke, as well, moreover, as the nature and quantity of the bye-products, and their relative proportions, were affected only by the scientific and rational working of the oven. The engineer had now at his disposal a large number of practical data, and he was able to modify the details of his oven to suit the mode of manufacture that might be selected. It was self-evident that the advantages of bye-product recovery were proportional to the percentage of volatile matter in the coal to be treated. The utilization of the waste-gases was only possible for coals containing above 20 per cent.; and when it exceeded 22 or 23 per cent., it deserved the earnest attention of the manufacturer. The volume of gas in excess of

* "L'Utilisation. dans des Moteurs à explosion, des Gaz en excès provenant des Fours à coke à récupération," *Bulletin trimestriel de la Société de l'Industrie Minérale*, 1901, vol. xv., pages 493-501.

† Translated by Prof. Henry Louis, M.A.

that which was required to heat the oven was a function of the nature of the coal treated, its state of dryness, of the temperature of the air and of the gas at the burner, of the number and proper distribution of the burners, of the dimensions of the coke-ovens, of the thickness of the walls which separate the flues of the ovens, of the duration of burning, etc.

*Waste Gases.*—In Westphalia, it was estimated that the volume of the excess-gases might reach 25 per cent. of the total volume. This proportion seemed high, and the writer doubted whether it was the result of systematic measurements. Numerous data collected at the Lens collieries showed that, as a maximum, 12 per cent. of these excess-gases were produced under the following conditions:—Coal coked, 7 tons, containing 23 per cent. of volatile matter; moisture, 10 per cent.; and ash, 9 per cent. There are three burners and seven air-inlets per oven. The temperature of the air was 608° Fahr. (320° Cent.); and the temperature of the gas was 122° Fahr. (50° Cent.). The period of burning was 36 hours. The thickness of the flue-walls was 5 inches (13 centimetres). The production of purified gas of a specific gravity of 0·482 was 11,478 cubic feet (325 cubic metres) per ton of coal coked.

The excess of gas, originally employed to heat steam-boilers, boilers for distilling tar, stoves, etc., had been for the last two years partly utilized in a double-acting gas-engine, Letombe system, of 20 to 25 horse-power, working a dynamo. At the outset, this application presented rather serious difficulties, on account of the valves becoming choked by tar, but it had been completely successful since the gas had been purified before use.

A coke-box, a kind of scrubber, and an oxide-of-iron purifier remove the tar and the sulphur. This purification, at present indispensable, necessarily caused a certain amount of complication. The recovery apparatus is being extended by additions, designed by the Société des Compteurs, and the Deutsch Continental Gaz Gesellschaft, for the recovery of cyanogen and sulphur. By this means, the gas will return to the oven or will enter the cylinder of the gas-engine after the successive and profitable recovery of the tar, naphthalene, cyanogen, ammonia, benzol, and of the sulphur, of which latter the absorbants used will be charged up to 50 per cent. on account of the previous extraction of the cyanogen.

The specific gravity of the purified gases of the Lens coke-ovens is 0·614. Its calorific power at 59° Fahr. (15° Cent.) is 475 British thermal units per cubic foot, or 4,200 calories per cubic metre.

*Available Power.*—The quantity of gas arising from 120 coke-ovens, taking 7 tons loads and burning for 36 hours, under favourable conditions, is 35,000 cubic feet (1,000 cubic metres) per hour, and this with a consumption of 29 cubic feet (830 litres) per indicated horsepower (figures given by experiment, as will be shown below) represents (35,000 ÷ 29 = ) 1,200 indicated horsepower, or say 10 horsepower for each coke-oven at work.

TABLE I.

| Experiment. | No. 1. | No. 2. |
|---|---|---|
| Duration of trial ... ... ... | 3 hours 5 minutes ... | 4 hours. |
| Volume of gas used, at 0° Cent. and 760 millimetres ... .. | 55·910 cubic metres | 75·928 cubic metres. |
| Do. do. ... | 1,974 cubic feet ... | 2,681 cubic feet. |
| Volume of gas used per hour, at 0° Cent. and 760 millimetres... | 18·132 cubic metres | 18·982 cubic metres. |
| Do. do. | 640·21 cubic feet ... | 670·25 cubic feet. |
| Indicated horsepower ... ... | 21·99 ... ... | 24·536. |
| Volume of gas used per indicated horsepower, at 0° Cent. and 760 millimetres ... . | 0·827 cubic metre ... | 0·773 cubic metre. |
| Do. do. .. | 29·2 cubic feet ... | 27·3 cubic feet. |
| Dynamo:—Volts ... ... ... | 127·33 ... ... | 131. |
| Ampères ... ... | 89·91 ... ... | 96. |
| Watts ... ... | 12,090 ... ... | 12,587. |
| Horsepower ... ... | 16·42 ... ... | 17·10. |
| Volume of gas used per electric horsepower, at 0° Cent. and 760 millimetres ... ... | 1·104 cubic metres... | 1·110 cubic metres. |
| Do. do. ... | 39·0 cubic feet ... | 39·2 cubic feet. |
| Calorific power of 1 cubic metre of gas, at 0° Cent. and 760 millimetres ... ... ... | 4,410 calories | 4,410 calories. |
| Specific gravity of the gas ... | 0·482 ... ... | 0·482. |
| Electric efficiency ... ... ... | 0·746 ... ... | 0·697. |
| Thermic efficiency, calculated from the indicated horsepower | 0·174 ... ... | 0·186. |
| Thermic efficiency, calculated from the electric horsepower | 0·130 ... ... | 0·129. |

On the other hand, the waste-gases of bye-product ovens vapourize a mean quantity of 0·75 pound of water per pound of coal coked; or, allowing 33 pounds (15 kilogrammes) of steam per indicated horsepower per hour, about 9½ horsepower per oven.

It is remarkable that the production of steam from an ordinary coke-oven, on the basis of 1·40 pounds of steam per pound of coal coked, the mean obtained in practice, develops exactly the same power.

Thus, the employment of explosion-motors for the utilization of coke-oven gases renders available the whole of the power that can be obtained from the waste-gases of an ordinary coke-oven.

The experimental data (Table I.) show a consumption per indicated horsepower of about 29 cubic feet (0·827 litres) of gases, developing 475 thermal units per cubic foot or 4,200 calories per cubic metre. The electric efficiency of 0·746 is a remarkable result, considering that it had been obtained by a motor of an old type and rather worn out. This must be considered not as characteristic of a motor of recent and improved type, but as an indication of the advantage that can be obtained from the waste-gases of bye-product coke-ovens, when these are burnt directly in the cylinder of a motor.

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Mr. E. Reumaux wrote that, since the paper was written, he had modified the distribution of the gases in the flues of the coke-ovens and the temperature of the coking, with the result that the volume of waste gases was much increased. He estimated that the disposable volume was now 18 per cent. instead of the 12 per cent. indicated in his paper, so that each coke-oven would now yield about 15 horsepower.

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## DISCUSSION OF MR. EMERSON BAINBRIDGE'S PAPER ON "AN ELECTRIC PUMP FOR UNDERGROUND USE."*

Mr. J. S. Dixon said that the pump described by Mr. Bainbridge seemed to be exceptional on account of its very short stroke, and he asked whether, when practically tested, it had proved satisfactory.

Mr. M. Walton Brown said that he did not know whether the Hadfield pump, with a stroke of 1 inch, had been tested, but the Ljungström engine, which had a stroke of only $\frac{13}{16}$ inch, had been tested with satisfactory results.† It was an exceedingly small

* *Trans. Inst. M. E.*, 1900, vol. xix., page 346. † *Ibid.*, vol. xviii., page 433.

and compact apparatus occupying a few cubic feet of space,* and at the high speed at which it runs develops from 15 to 20 horsepower. It seemed a toy, when seen driving an electric dynamo of much greater dimensions.

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## DISCUSSION OF MR. EDWARD GLEDHILL'S PAPER ON "THE ANALOGY BETWEEN THE GOLD 'CINTAS' OF COLOMBIA AND THE AURIFEROUS GRAVELS OF CALIFORNIA."†

Mr. W. S. Welton (Wembley) wrote that he considered the study of auriferous gravels to be of considerable importance, and he believed it would lead to the discovery of deep deposits of great richness in gold, the finding of which appeared only to have been impeded by too much importance having been attached to the term "alluvial," and the ancient-river theory of their deposit, which had been applied to auriferous gravels in particular to distinguish them from other gravels. From long observation he saw no reason to doubt that rich gravel-deposits would be found at depths of 1,000 feet and more from the present surface. The composition of the older deposits of gravels appeared to be very similar all over the world and, as to their depth, he might mention an extensive auriferous gravel-deposit of 1,200 feet in depth, in Colombia, near the town of Bucaramanga, made up of a number of beds of gravel, of varying coarseness, with beds of sand or sandstone interposed. The depth of this bed had been exposed by the wearing down caused by a large river flowing over it and, but for this, any of the beds of sandstone might be taken to be the bed-rock. In Tuolumne county, California, U.S.A., gravel-deposits had been worked with 1,000 feet of cover of lava at Table Mountain, and 10 square feet of area was reported to have yielded £20,000 (100,000 dollars) in gold, and 1 pint of gravel not unfrequently contained 1 pound of gold.‡

Until recently, estimates of the value of auriferous gravel-deposits had generally been based upon pan-tests, but as the gold is very unequally distributed through the gravel-beds and there

* An engine of 16 horsepower measures 13 inches by 14 inches by 20 inches and weighs 85 pounds.

† *Trans. Inst. M.E.*, 1900, vol. xx., page 391.

‡ *Reports on the Mineral Resources of the United States*, Government Printing Office, 1867.

are no means of exactly ascertaining the necessary deductions to be made for large boulders and barren sand-beds, no reliance could be placed upon such data as a test of the loss sustained in the extraction by the hydraulic system of working. The results of panning are not unfrequently stated in "colours" to the pan, a very indefinite measure upon which to base probable results.*

If the losses of gold by hydraulic treatment were very great, and larger in proportion to the quantity of water employed, it might be expected that the tailings from mines like those of the Spring Valley and North Bloomfield companies would be rich and pay for retreatment, but this had not been found to be the case. It might be mentioned that where large volumes of water are used the sluices are proportionately enlarged. At the Spring Valley works the lower sluices are 16 feet in width, the upper ones, carrying about 1,000 inches of water each, being 4 feet wide, and several faces are worked simultaneously.

The writer worked for some years on the ground-sluice system, and comparing the results obtained from the cubic contents of the excavation made with those obtained afterwards by the hydraulic system, subsequently introduced, the yield appeared to be somewhat larger by the first system, but by the hand system, the pay-dirt was broken with the least addition of barren ground and boulders, whereas by the hydraulic system, working day and night, the whole of the ground, rich and poor, was carried off for the convenience of piping, and this appeared to account for the lower produce per cubic yard of dirt run off. In ground-sluicing, all the boulders and a large portion of the pebbles remain and are piled up on each side of the sluice, and only comparatively shallow deposits can be worked by this means on account of the accumulation of the tailings in the neighbourhood of the sluice and the cost of carrying out the waste by hand.

With regard to the pollution of rivers: cattle and sheep did not suffer from drinking the water from the mines, but if used for irrigation it had a bad effect on grass and other plants through covering the surface with mud and excluding the air.

In dredging, the after treatment of the gravel would be by sluice, but there would be a great loss of gold in raising the gravel to the surface unless there was much clay in the gravel. By the wingdam system, the bed-rock of rivers could be cleaned up per-

* He had found that about 300 average "colours" of gold weigh 1 grain Troy.

fectly, and in most instances this system would be less costly than the erection and working of dredgers in places where there might be no coal and the carriage of heavy machinery might be costly.

Mr. A. H. Bromly (London) wrote that Mr. Gledhill stated that a "pan of gravel contains about ½ cubic foot, or say, 54 pans per cubic yard."* It is customary in the Western States of America to regard 120 pans as being equivalent to 1 cubic yard, and a few simple calculations will show that this number is correct. The size of pans varies, but an ordinary size is 17 inches in diameter at the top, 11 inches in diameter at the bottom, by 3 inches deep, and the contents, without heaping, are 461 cubic inches; or, 3¾ pans per cubic foot. The swell of loose gravel, above its original bulk in the bank, is about one-fifth, so that 1 cubic yard in the bank occupies about 1·20 cubic yards in the measuring-box. Consequently, the equivalent of loose gravel to be panned, as representing 1 cubic yard, is (27 cubic feet plus $\frac{1}{5}$, or) 32½ cubic feet, which multiplied by 3¾, equals 121·8 pans; and in his (Mr. Bromly's) practice, he took 125 pans as being an average. It is probable that Mr. Gledhill refers to a local and larger type of pan than that in ordinary use.

Mr. G. K. Radford wrote that although there is doubtless some foundation for Mr. Gledhill's opinion as to the probable amount of gold lost during the hydraulicking of a mass of gravel, yet that such differences of results between the prospector and the operator arise mainly from errors of judgment as well as designed misstatements. It must be considered that to estimate, with anything like reasonable correctness, the value of any gravel mine, a very careful and prolonged survey, accompanied by many borings, must be made of the area supposed to contain gold before the judgment and experience of the mining engineer comes into play. He (Mr. Radford) has personal knowledge of such a district in Ecuador, where a very considerable area was represented as being covered by an immense number of millions of cubic feet of gravel containing gold, with every facility for washing; but which upon examination by honest and competent men, was proved to contain a few washed-out patches of gravel upon points of the river, where the former Spanish and Indian miners had located. This was clearly a case of either very ignorant or

* *Trans. Inst. M.E.*, 1900, vol. xx., page 397.

designedly misstatement, and numerous similar cases are of constant occurrence.

No account is taken in many cases of the large gravels and boulders, which are thrown out of the excavated mass before washing in the pan, but which form a part of the cubic contents of the area; necessarily reducing the percentage of gold derived therefrom upon subsequent working by the monitor and sluice.

Judgment and experience are required to determine the rate of inclination of the sluice boxes so as to properly carry off the materials washed down by the monitor; boulders and coarse gravel necessarily require more grade than fine, and although to the uninitiated eye, the speed of the current appears to be excessive, it should be remembered that the particles of gold are heavy, as compared with water, and sink rapidly aided by the attractive force of the mercury. From 80 to 90 per cent. of the gold is found in the first few boxes, and it is due to the eddies that deposition is effected. It is of course possible to overdo the length of under-currents, the last ones often merely yielding sufficient to pay for their maintenance.

Upon the whole he (Mr. Radford) is inclined to believe that much better results can be attained than 50 per cent. of the pan-returns, as stated by Mr. Gledhill.

There appeared to be some discrepancy in the statement as to weights and contents of bateas. Thus, Mr. Gledhill states that a cubic yard of gold-gravel weighs 1·8 tons or 4,032 pounds; a pan of gravel equals ½ cubic foot or 54 pans to a cubic yard, and 74½ pounds per pan; and a cubic yard of gravel contains 100 bateas-full or 40·32 pounds per batea. In California, 18 cubic feet to 2,000 pounds, or 111 pounds per cubic foot, is generally taken as the weight of gravel, and 20 to 25 pounds as the weight of a pan-full.

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## DISCUSSION OF MR. H. D. HOSKOLD'S "NOTES UPON ANCIENT AND MODERN SURVEYING, ETC."*

Mr. H. D. Hoskold (Buenos Aires) wrote that he had no opportunity of correcting the proofs of his paper. It was, therefore, surprising that a larger number of typographical errors had not been found. Naturally, he is obliged to anyone kind

* *Trans. Inst. M.E.*, 1900, vol. xix., page 171; and vol. xx., page 499.

enough to indicate such errors as may exist with a view to their final correction.

Apart from the interest which might be considered to attach to the history of what had been done upon the continent of Europe in the olden times, and the doings in France and the United States, which Mr. Brough had wedged in like an intrusive dyke, placed upon a geological coloured section in order to render its appearance more imposing and important, he (Mr. Hoskold) failed to discover anything of an adverse nature in Mr. Brough's comments, upon a very small and the least important portion of his paper, worthy of serious attention, or forcibly calling for an elaborate reply. True there is nothing like accuracy when no untoward circumstances beyond control occur to mar it. When in the act of criticizing, Mr. Brough is not free from inconsistency, error and a careless mode of representing facts and persons.

The mining surveying-instrument of Mr. Combes, 1836, is not a proper transit, but it is essentially what is termed among scientific and practical surveyors and others, an eccentric one,* that is, the telescope is attached to one of the sides of the divided horizontal circle and, consequently, it is not similar to his (Mr. Hoskold's) miner's transit-theodolite of 1863,† which has the telescope supported to revolve in a vertical plane over the centre of the divided horizontal circle. Neither is Mr. Combes' instrument similar to his (Mr. Hoskold's) civil and mining engineer's transit-theodolite of 1900, or to either of the other surveying instruments introduced by him, except his angleometer of 1870,‡ which is of the same type, but in construction and use is vastly superior to that of Mr. Combes.

The writer had not "elaborated" the paper which he published in the *Transactions* of the American Institute of Mining Engineers§ to form the one published in our *Transactions*, but the latter was "elaborated," as Mr. Brough pleases to call it, and is in fact an extension of the paper which the writer was invited to draft upon Geodetic Surveying, for the American Society of Civil Engineers in 1892, for the Engineering Congress at Chicago in 1893, and that paper was published in their *Transactions*.‖

* *Trans. Inst. M.E.*, vol. xix., page 234.

† *Ibid.*, vol. xix., page 237.

‡ *Ibid.*, vol. xix., page 231.

§ 1900, vol. xxix., pages 955 to 983.

‖ 1893, vol. xxx., pages 135 to 154.

With regard to the footnotes of reference, the omission of which had caused a sad disturbance in Mr. Brough's mind, it was only proper and charitable on his (Mr. Hoskold's) part to leave room for aspiring younger authors to expand, improve and fill up any deficiency, according to their modern ideas of acquired foreign knowledge, which it was insinuated had been denied to the writer. At the same time, Englishmen, as a rule, were mostly concerned with that which had been done, was now doing, and what might be expected to be done in the future in their own country. Surveying instruments and surveying conjoined formed a very important subject, which, however, neither the French, Germans, nor North Americans had as yet exhausted, neither had they instructed us in anything new referring to it.

He (Mr. Hoskold) had nothing at present to add to his paper, further than simply to refer to a few incidental circumstances and especially to our great predecessor Gascoign, an excellent English astronomer, and who between 1638 and 1643, was the first to invent and apply a distant measurer.* This circumstance was exceedingly important as proving beyond dispute Mr. Brough's statement in his criticism, that "in dealing with questions of priority it is impossible to exercise too great care;"† but this rule had not always been adhered to by Mr. Brough, as is plainly manifested by what follows. In 1888, Mr. Brough asserted that Mr. William Green was the first to apply the "tacheometric principle in surveying" some little time prior to 1778, but in 1900 Mr. Brough changed his opinion and stated that "its real discoverer was James Watt, who used it in 1771 for measuring distances in surveys for the Tarbert and Crinan Canals."‡ He (Mr. Hoskold) had nevertheless demonstrated in a positive manner that the priority of the discovery of the tacheometric principle and its application was due to Gascoign, who invented a special instrument and also used it in determining distances on the surface of the earth somewhere between 1638 and 1643. This statement was confirmed in the most distinct and positive form by such distinguished and undoubted authorities as Oughtred, Townley, Flamsteed, Pearson, Mackenzie, and others, as he (Mr. Hoskold) had shown in his second paper or contribu-

* *Trans. Inst. M.E.*, 1900, vol. xix., page 184. † *Ibid.*, vol. xx. page 500.

‡ *Transactions of the American Institute of Mining Engineers*, 1900, vol. xxix., pages 934-935.

tion to the discussion of Mr. Dunbar D. Scott's paper on the "Evolution of Mine-surveying Instruments."*

Mr. Brough has constantly accepted and propagated the idea that Flavio Gioja (1302 to 1320) was the first to "enclose a magnetic needle in a box;" but in his comments upon his (Mr. Hoskold's) paper, the assignment is made to a foreign poet Guyot de Provins, 1190, and then Mr. Brough boldly states unjustifiably that "the French priority of invention is supported by the fact that on compass-cards in all countries the north is marked with a *fleur-de-lis*."† The deduction of Mr. Brough just cited is, however, neither reasonable nor logical, for the fact of all nationalities having adopted the *fleur-de-lis* as an ornament is no proof of priority of invention, introduction or use. In fact, upon such grounds, either of the nations which may be included in his "all countries" may have been the inventor or first introducer or user. Mr. Brough has found it impossible to give any authority, creditable or otherwise, in support of his assertion, therefore there is no evidence proving that the priority of such an invention is due to the French.

The English monk, Neckham, lived in the twelfth century, and somewhere between 1170 and 1180, he wrote two Latin books, that is, *De Natura Rerum* and *De Utensilibus*, and in both of these the magnetic needle was referred to; but especially so in one of them, as a thing common in his time. Neither the Italian Gioja, if he were such (1302 to 1320) nor the Frenchman Guyot de Provins (1190), can therefore be made to supplant the proved prior claim of our Englishman, Neckham.

The question of the invention and introduction of the magnetic needle had frequently been discussed, and various opinions emitted without arriving at any definite or satisfactory decision or solution, and even Mr. Brough himself, who had written so much about it, had never exhibited any consistency in his assertions. For example, in his treatises on *Mine-surveying*, editions from 1880 to 1899, he had always stated that "the use of the magnetic needle for surveying mines is first described by Georgius Agricola in the fifth book of his *De Re Metallicâ* published in 1556." Mr. Dunbar D. Scott appeared to have included in his paper, previously

* *Transactions of the American Institute of Mining Engineers*, 1902, vol. xxxi., page .

† *Trans. Inst. M.E.*, 1900, vol. xx., page 500.

referred to, the last preceding passage referring to Agricola, and had taken it apparently from Mr. Brough's book, at least both authors agree in sense and nearly in choice of words; but in his criticism, when referring to Mr. Scott's paper, he (Mr. Brough) said that "the author is inaccurate in stating that the use of the compass [magnetic needle] in mine-surveys is first described by Agricola."* It was scarcely necessary to note the strange contradiction in terms which Mr. Brough had employed.

He (Mr. Hoskold) was correct, and not "scarcely," but perfectly justified in reference to what he had stated in his paper about his book upon *Mine-surveying*, 1863, and further that he had written nothing from memory in his paper without refreshing it by reference to proper authorities, and also that he knew for more than 50 years that the title of Houghton's book was *Rara Avis in Terris or the Compleat Miner*, in two books, and that his small treatise on subterranean surveying is entitled *Some Examples of Dialling*. The edition in his possession is dated, 1738, and the last page of Houghton's *Dialling, or Underground Surveying* is dated 1681. Mr. Brough states, in effect, what most people know, that the words *Subterraneous Surveying* "is not the title of Houghton's book published in 1681."

As he (Mr. Hoskold) stated in his paper,† Budge published in 1845 *The Practical Miner's Guide* (Longman, London), and anyone well acquainted with English engineering literature might have concluded that it was the second and not the edition of 1825 to which he had referred.

Rickard, in his book, used the words "plain theodolite,"‡ but qualified them to mean "Wilton's improved miner's dial, without a vertical arc or telescope." That instrument could not, therefore, be compared to his (Mr. Hoskold's) miner's transit theodolite, 1863, Fig. 19 in his paper.§ Rickard never introduced a system of mine surveying by the exclusive use of such an instrument, nor indeed by the common English cradle or plain theodolite.

The misprint occurring in his paper was evident,|| but the diagram representing the theodelitus of Digges was the same in his book of 1571 and in the edition of 1591. Considering, there-

* *Transactions of the American Institute of Mining Engineers*, 1900, vol. xxix., page 932.

† *Trans. Inst. M.E.*, 1900, vol. xix., page 214. ‡ *Miner's Manual*, page 158.

§ *Trans. Inst. M.E.*, 1900, vol. xx., page 238. || *Ibid.*, pages 181 and 183.

fore, that no vital principle was affected either in science or practice by these misprints, it was difficult to discover what science and the profession could gain from the curious mode of criticism which Mr. Brough had chosen to adopt.

He (Mr. Hoskold) had nothing whatever to modify in his paper; on the contrary, however, he took this opportunity of confirming all that he had stated in it—barring of course any discoverable error in principle attributable to him—in a most emphatic manner. If, however, he should consider it necessary, he reserves the right to extend his reply on a future occasion.

The following corrections should be made in his paper printed in vol. xix. of the *Transactions*: Page 230, "coombe" in lines 15, 18 and 19 should read "combe;" page 237, "levelled" in the first line should have read "bevelled;" and the bottom line of page 181, and the top line of page 183, for "Fig. 3 represents page 35 of this curious book, with a diagram," should read "Page 182 is page 35 from Digges' curious book, second edition of 1591, and the diagram, Fig. 3, represents his theodelitus of 1571 and 1591."

Mr. M. Walton Brown wrote that the *fleur-de-lis* (Italian, *giglio*) was as ancient an historical badge of the city of Florence and of the Florentine republic, as it was of France.

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## DISCUSSION OF DR. HANS GOLDSCHMIDT'S PAPER ON "PRACTICAL APPLICATIONS OF THE PROCESS FOR THE PRODUCTION OF HIGH TEMPERATURES BY THE COMBUSTION OF ALUMINIUM."*

Mr. M. Walton Brown remarked that the Goldschmidt process for the production of high temperatures was founded on the affinity of aluminium for oxygen. On bringing these two elements together under certain conditions, a chemical reaction is started of so energetic a nature that a temperature, hitherto obtained only by electrical means, is generated with almost instantaneous rapidity. The oxygen necessary for the combustion is obtained from metallic oxides. Taking ferric oxide as an example, the chemical equation representing the reaction is $2\,Al + Fe_2O_3 = Al_2O_3 + 2\,Fe$; and metallic iron and alumina are the resultant products.

* *Trans. Inst. M.E.*, 1900, vol. xix., page 411.

On account of the highly basic nature of molten alumina and its consequent corrosive action, when in a molten state, on any refractory material of an acid nature, such as fire-clay or the like, a basic lining is absolutely necessary. Magnesia has great durability, but a lining of alumina, obtained from previous operations, is even more durable. A crucible lined with alumina is capable of withstanding, on the average, from five to ten different operations.

For the ignition of the admixture of powdered aluminium and metallic oxide, a high initial temperature is necessary. It is a wellknown fact that certain superoxides part readily with the extra oxygen at a comparatively low temperature, at the same time generating a very intense heat. By partly covering a small portion of admixed aluminium powder and a metallic oxide, placed at the bottom of the crucible, with a little mixed superoxide, preferably barium superoxide, and finely powdered aluminium, and igniting the latter with an ordinary wax vesta, the combustion is readily and quickly started. Once started, by the simple addition of more material to the white-hot mass, the combustion is prolonged at the will of the operator, quick or slow addition allowing of the regulation of the reaction and prevention of too rapid and energetic working. It has been found impossible to measure accurately the temperature generated, but it is estimated to be about 5,400° Fahr. As a result of the simplicity of the process, it is possible to apply a heat of an intense nature, at any required spot, without the aid of machinery or costly appliances.

The heating-agent, consisting of powdered aluminium and oxide of iron, has been patented and registered in all industrial countries under the names of "thermit" or "thermite." It is practically smokeless, and emits when burning no noxious fumes. It is not subject to spontaneous combustion, but the calorific power is diminished when exposed to a damp atmosphere. For the whole operation, the only appliances required are a slag-lined fire-clay crucible, a pair of tongs, a clamp, the necessary thermite, and a box of matches; the total weight of an outfit is about 50 pounds for welding pipes up to 4 inches in diameter, while larger pipes require slightly heavier inmplements.

In every application of the process, the mixture of aluminium and ferric oxide, or thermite is ignited, as previously explained,

in a crucible of a capacity corresponding to the dimensions of the material being heated. The white-hot fluid is then cast rapidly into the sheet-iron mould, until the joint is surrounded at every point by the molten mass.* Immediately on the solidification of the surface, which takes place almost immediately, a little sand is added to prevent unnecessary loss of heat. The requisite welding heat is imparted to wrought-iron tubes within 1½ minutes after casting, in the case of pipes, say 2½ inches in diameter and 0·17 inch in thickness; for smaller and larger sizes less or more time is required. At the expiration of the necessary interval, the clamps are shortened by about 0·08 inch, in order to assist the natural force exerted by the expansion in a confined area, after which the weld is complete.

It might be anticipated that on pouring the contents of the crucible upon the bars or tubes, the molten iron would immediately attach itself to the same on account of its high temperature. This is not the case, as will be readily understood from the following explanation:—In the crucible are two separate and distinct fluids, the molten metal regulus below and the alumina or slag on the top. On emptying the crucible, the molten alumina is first poured upon the joint and as it solidifies to a slight extent immediately on coming into contact with the cold metal a refractory layer or lining is formed, which effectively resists the heat of the molten regulus and prevents it from attaching itself to the iron. In like manner, a refractory layer of molten alumina is formed upon the sheet-iron mould, preserving it from being quickly destroyed. Particular attention may be drawn to the fact that the weld is perfectly clean and complete, no more work being necessary; and that the process is applicable for welding cast-steel tubes or pipes.

The implements employed for the welding of rails are similar in most respects to those employed for the welding of tubes, except that they are much heavier and the quantity of thermite used for individual welds is much larger. As a result of the almost perfect connection obtained by the welding of rails, it may be mentioned that the return electric current is conducted with much less loss than formerly. This is a great gain to gas and water

* *Trans. Inst. M.E.*, vol. xix, Fig. 2, page 417; Fig. 4, page 419; Fig. 5, page 420; Fig. 6, page 421; and Fig. 11, page 423.

companies, as the leakage of the return current resulting from bad connections is responsible for the short life of the pipes in the neighbourhood of electric railways.

The process is applicable at mines for repairs to broken teeth of wheels, etc. Fig. 13* is a section of a spur-wheel, showing a new tooth, welded into position, in place of a broken one. It has been found possible to repair broken rolls, 12 to 30 inches in diameter, which may have given way owing to excessive strain. After warming and surrounding the ends with a suitable mould, molten iron produced from thermite is poured on the broken face, which is placed in a horizontal position, and this is immediately followed by a further amount of steel from a Bessemer converter. If care be taken in shaping the mould, very little subsequent work is necessary.

The quantity of thermite used in welding pipes or bars up to 6 inches in diameter appears to range from 3 to 6 pounds per square inch of section.

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Mr. ARTHUR O. WHEELER'S "Notes on the Field-work of Photographic Surveying as applied in Canada," was read as follows:—

* *Trans. Inst. M. E.*, 1900, vol. xix., page 426.

# NOTES ON THE FIELD-WORK OF PHOTOGRAPHIC SURVEYING AS APPLIED IN CANADA.

By ARTHUR O. WHEELER, D.L.S.,
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*Introduction.*—The writer submits the following notes with some reluctance, for the reason that the subject is one of interest to the topographer and surveyor rather than to the engineer. While the method is specially suited to the mapping of mining districts and surveys in connection with the exploration for, and location of, railways in mountain-regions, it can scarcely be said to apply to engineering problems in particular, unless it be to those of the irrigation-engineer.

Colonel A. Laussedat, member of the Institute of France and director of the Conservatoire National des Arts et Metiers, is the originator of the method as far back as 1849. He still continues his investigations, and watches its development with interest; for not long ago the writer received from him a very valuable and scientific paper entitled "La Métrophotographie," presented to the French Society of Photography, in which he did the writer the great honour of recognizing his first attempts in this direction.

The application to Canadian topographical surveys is due to Mr. E. Deville, Surveyor-general of Dominion Lands. His efforts have been attended by much success, and his valuable and complete work, entitled *Photographic Surveying*, published in 1895, not only treats fully of the theory of the subject and the methods employed upon Canadian Surveys, but briefly reviews its conception, progress and the methods employed elsewhere.*

In Canada, the principal surveys upon which the method has been employed are: (1) Survey of a portion of the Rocky Mountains, by Messrs. J. J. McArthur, D.L.S., and W. S. Drewry,

* The writer transmitted a copy of this work, kindly furnished by Mr. Deville for the purpose. Copies may be purchased from Messrs. James Hope and Sons, Stationers, Ottawa, Ontario, Canada.

D.L.S.; (2) survey of a portion of Alaska and the Yukon district in connection with the establishment of the boundary-line between Alaska and the said district, under the superintendence of Mr. W. F. King, D.T.S., Boundary Commissioner; (3) survey of a portion of the Alberta watershed for irrigation purposes, by the writer; (4) a number of minor surveys in the Yukon district, on the Columbia river and in the Kootenay mining district, by Messrs. J. J. McArthur, W. S. Drewry and A. St. Cyr; and lastly (5) a survey of the Crow's Nest coal-area, during the past summer, by the writer.

It is not the writer's intention to enter into the theory of the science, as space would not permit, and Mr. Deville's valuable work leaves little to be said on the subject by a beginner; but in order to understand the following notes, it is necessary to say that the photographs taken are perspectives from which, by the rules of geometry and the inverse problem of perspective, contour-lines for any visible part may be reduced to a ground-plan. The elevation above a given datum and the position of the camera-station being known, any point in a view can be projected on the ground-plan. It is, however, essential that points so projected should be recognizable in two views taken at different stations, and that the two stations and the point form the apices of a fairly well conditioned triangle. In other words, the imaginary line between the stations is a base subtending an angle of which the point to be projected is at the apex, the accuracy with which it is projected depending relatively upon the closeness of the angle to 90 degrees.

On the plan, the points are placed in position by projecting thereon the traces of the horizon and principal lines of the two views, and the lines of sight from each camera-station to the said points. The intersection of the projection of the lines of sight fixes the position of the point. The traces of the horizon and principal lines are required for plotting these lines of direction.

A sufficient number of points along the ridges and dividing water-courses of the area embraced by the two views are identified and projected on the plan, care being taken to select those that will give the best definition of the ground. In order to draw the contour-lines in proper position, it is necessary to have the relative elevation above datum-level of the points laid down.

These elevations are based upon the elevation of the stations from which the views are taken, and are obtained directly from the photographs. The horizon-line corresponds to the altitude of the station. The elevation of any point in a photograph is proportional to its height above or below the horizon-line and the distance that its projection falls within or beyond the trace of that horizon-line. By means of the scale referred to in Mr. Deville's book, elevations are readily obtained, and subsequently contours are drawn in the proper position. Elevations should be taken out from both photographs, and thus made to check one another.

The above is the fundamental principle of the method; there are, however, numerous constructions that assist in obtaining elevations and definition of figures in planes parallel or inclined to the ground-plane. For the most part these require the use of perspective instruments, such as the perspectograph, perspectometer, centrolinead and photograph-board.

One of the most useful and interesting constructions is the method of squares: The perspective of a series of squares is placed upon the photograph, either by drawing or by using the perspectometer. The squares are then projected upon the plan, or such portion of the series as may be required, and the figure which it is desired to trace is drawn at sight. By this means, large streams flowing through wide, heavily timbered valleys, can be accurately delineated from a rapidly made camera-survey, where ordinary survey-methods would require a party of axemen and the expenditure of much labour and time, with results not nearly so accurate in detail. The same applies in many other cases, such as lakes, irrigation-systems, towns, villages, parks, etc., provided that suitable camera-stations can be obtained at a sufficient elevation to disclose the details of the area to be mapped, and that the plane of the area is near enough to the horizontal to be within the accuracy of the scale employed. Certain figures in inclined planes can be referred to the horizontal by using the proper constructions.

*Field Work.*—From the foregoing, it will be seen that the results obtained depend upon the accuracy with which the camera-stations are fixed in position and elevation. A triangulation carried to a greater or less degree of refinement is generally employed for this purpose. In the survey of the Alberta water-

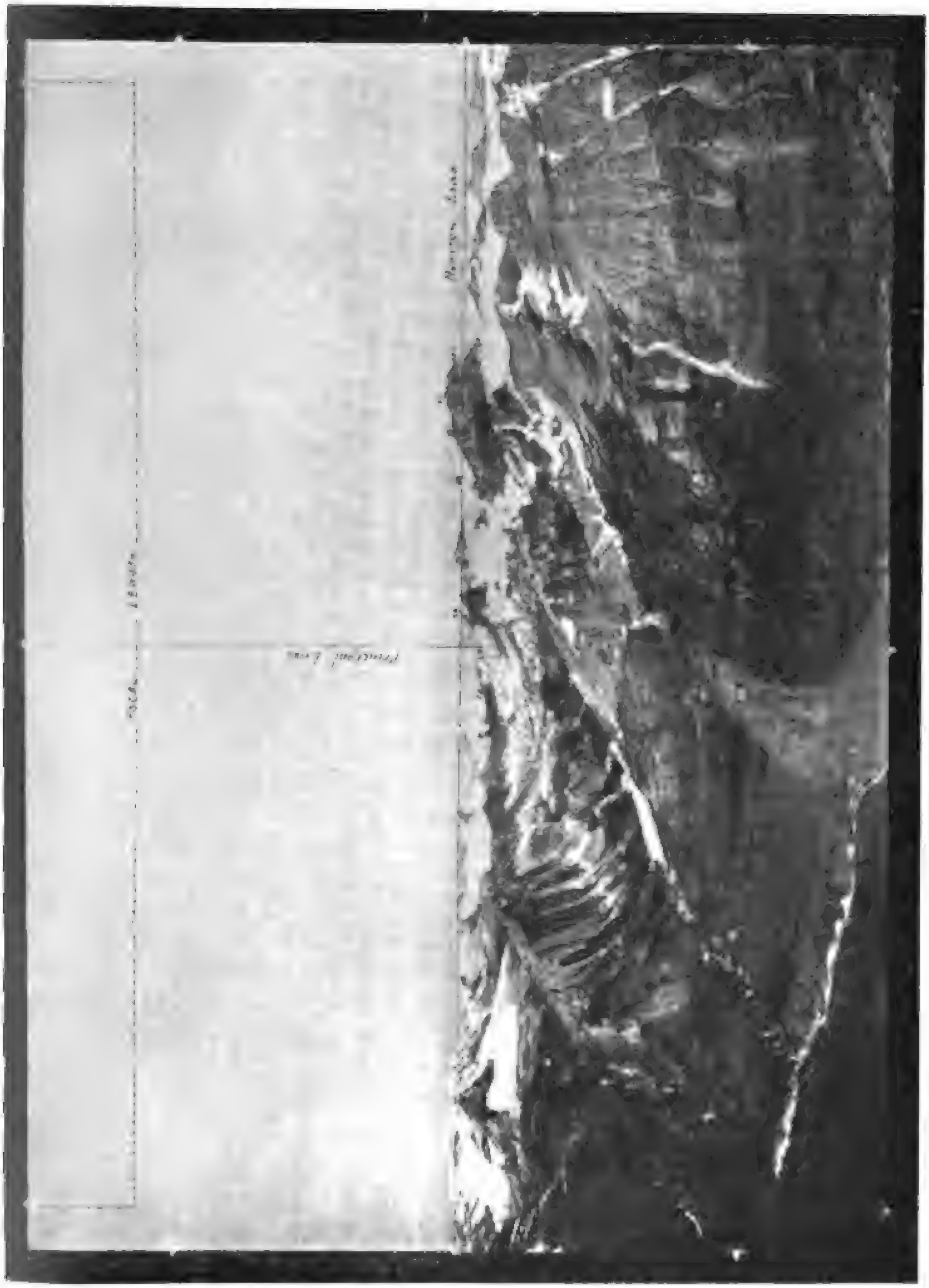


FIG. 1.—VIEW FROM BOUNDARY STATION.

shed, a primary triangulation was projected over the area in advance of the photographing. It was carried to a fair degree of accuracy, the work being done by a 7 inches transit-theodolite reading to 10 seconds and checked at intervals by carefully measured base-lines. The sides of the triangles averaged about 15 miles. A secondary triangulation rested upon the primary, and fixed the position of the principal summits. For this purpose, a 4 inches transit-theodolite was used, reading to 0·01 degree. Camera-stations were located by readings to or from them as found most suitable.

At primary points, the signals sighted upon consisted of diamond-shaped drums of white cotton stretched upon a frame attached to a pole, 12 to 15 feet long, surmounted by a white cotton flag. The drum is raised about 6 feet from the ground, and measures 4 feet from the upper to the lower apex. With the sun in the right direction, no difficulty is experienced in sighting upon either apex at a distance of 25 miles.

For secondary and camera-stations two white cotton targets, set at right angles on a centre pole with a flag, were found all that could be desired.

In timbered areas, material for the foregoing can generally be found at or near the station and only wire for guys, cotton and nails need be carried up. The assistant can make the signal while the surveyor does the photographing. In mountainous regions, when the stations are above the timber-line, other signals must be employed, chiefly rock-cairns.

It is not necessary that the views be taken at the signal: generally, more advantageous and commanding points are found at some distance.

Camera-stations may be located by one of four methods:—

(1) If close, by taking at the signal the azimuth from a convenient primary or secondary point, and measuring the distance with a tape; this is the easiest and most accurate method.

(2) If distant from the signal or an independent summit, by erecting a signal and reading upon it with the transit from outside fixed points.

(3) By taking one reading upon it from an outside fixed point, and at the station two readings on other fixed points.

(4) By taking four or more readings at the station on outside fixed points.

To utilize the third and fourth methods when constructing the map, the readings are plotted on tracing-paper and lines drawn in the directions obtained. The paper is shifted around until each line passes through the station to which it belongs. The point from which the lines radiate is then at the location of the station on the map, and can be pricked through.

The last method may be advantageously used in the absence of an organized system of triangulation, when the survey is of an exploratory nature and is not carried to a high degree of accuracy.

Most topographical maps are referred to sea-level as a datum; it is therefore necessary that the elevation be carried from some point of known altitude and applied to all the stations of the survey. The relative elevations are obtained from vertical angular readings with the transit-instrument, carried to a greater or less degree of refinement.

It will be readily conceived that a difficulty is experienced in finding camera-stations, sufficiently commanding, to overlook deep valleys and the streams, roadways, etc., passing through them; also that projecting spurs will frequently obstruct the view. To obviate this difficulty and ascertain the points where contour-lines cross, traverses have been conducted up the main water-ways, road-beds and pack-trails. The lines of direction for such traverses are obtained by angular transit-readings at each station, commencing at a point of known position, and are referred to the astronomical meridian. The elevation is carried through by vertical angular readings at each station, back and forward. For distance, some pattern of stadia or micrometer is used. The ordinary chain would be impossible or too slow, requiring a large gang of axemen and chain-bearers.

In the Alberta watershed and Crow's Nest surveys, a modified form of the Lugeol micrometer has been employed. It is manufactured by Mr. A. Hurlimann, of Paris, and has been found to give adequate results. Sights can be taken up to 1 mile in length, from side to side, or point to point, of the valley at sufficient elevation to overlook the heavy timber generally found


FIG. 2.—VIEW FROM [illegible] STATION.

in the bottoms. It consists simply of a telescope, having a bisected object-glass, one of the halves being movable along the line of section by a screw. Two images are formed in the field by the bisected lens. Distances are determined by the number of screw-revolutions necessary to bring, into optical coincidence, the upper and lower targets of the reflected images. The targets are best made of white opal glass set in wooden frames, and are fastened to a rod at a known distance apart: say 15 to 20 links (10 to 13 feet). This is called the base; it is generally furnished with an iron shoe and is stuck in the ground in a vertical position, the targets extending side-ways at right angles. Attached to the screw of the movable half of the object-glass is a graduated head which measures in revolutions and hundreths the section of arc passed over in making the coincidence of the targets. It is merely necessary to find the value of a revolution, in order to enable the distance to be determined for each reading. Tables can readily be constructed so that distances can be taken out by inspection.

The instrument is subject to error from three principal sources:—(1) Error due to uneven refraction; (2) error due to wear-and-tear of the screw in the most used parts; and (3) error due to the base not being held perpendicular to the line of sight and the station being at a different altitude. The third error may be corrected by using the vertical angles read at each station with the transit. The first and second errors can only be reduced to a minimum by multiplying the readings.

The distance error of a traverse of this description varies from 1 in 250 to 1 in 400. By checking frequently upon the triangulation and camera-work, it is all that can be desired for the purpose.

From 4 to 6 miles per day can be accomplished over very rough ground by a party of three men.

The surveyor's compass is sometimes substituted for the transit-theodolite but is not so satisfactory, although more rapid.

The depth of the bottom of the valley below the traverse-station is measured by an aneroid barometer with sufficiently close results.

The country passed over is rapidly sketched in the field-notes of the traverse and these notes are found very useful to show where the affluent watercourses between the ridges join a main stream, also minor details that cannot be covered by the camera.

*Photographing.*—The camera and mountain transit used in connection therewith are fully explained and illustrated in Mr. Deville's book. It is first necessary to adjust the camera carefully, so that the true focal length may be marked by notches on the metal frame against which the plate presses. These notches are reproduced on every view taken, and give the focal length of the bromide enlargements used to plot the survey (Figs. 1, 2, 3 and 4). It is further necessary to obtain the readings of the spirit-levels attached to the camera, when the plate to be exposed is in a true vertical position. As it is essential that the plate be vertical when the view is taken, the adjustment must be very carefully made and requires some skill.

Upon Canadian surveys, a slow isochromatic plate has been used. It is manufactured by Mr. J. B. Edwards, of London, England, or by Mr. G. Cramer, of St. Louis, Missouri, U.S.A.; as the latter firm has, the writer understands, bought out the American patent of the former, both are practically the same plate.

All views are photographed through an orange or lemon-coloured screen, to equalize, as nearly as possible, the time of exposure required for the various coloured rays and to admit of a sufficiently long exposure to obtain detail in the shadows.

Before commencing work, it is necessary to find the unit of exposure for the batch of plates about to be used. This should be done as near as possible to the field of operations, as the altitude and character of the country are factors of considerable importance.

On a bright unclouded day at or near noon, a number of plates are exposed to a distant landscape. The greater the variety of contour and colouring the better, such as: timbered hills, grassy slopes, rocky ridges, mountain-streams or glassy lakes. Exposures may be given for 10, 20, 30 and 40 seconds to the same view, and the plates are then taken to the dark room and developed. Having developed the test-plates to as nearly as possible the same density, it is an easy matter to select the time giving the best general results. This may be accepted as the unit of exposure.

The exposure for any particular view, at any altitude, time


FIG. 3.—VIEW FROM NORTH FORK STATION.

of the year, and hour of the day, may now be obtained from the table given on page 188 of Mr. Deville's book. The table is adapted to 50 degrees of north latitude from the investigations of Messrs. Hurter and Driffield. The time so obtained is for light coming from a clear sky, and a proper increase has to be made for other stages of light. On the same page and the page following it is stated that Messrs. Hurter and Driffield, in the instructions for their actinograph, adopt five degrees of brightness, for which they give co-efficients of the unit of exposure. With orthochromatic plates and an orange screen the proportions given are as follows:—

| | | | |
|---|---|---|---|
| Very bright ... ... | 1·0 | Dull ... ... | 4·0 |
| Bright ... ... ... | 1·5 | Very dull ... | 8·0 |
| Mean ... ... | 2·0 | | |

Very bright is described as light coming from a pure sky; mean is when the sun casts a very faint shadow; very dull, the least light in which it would be advisable to photograph; bright is between very bright and the mean, and dull between the mean and very dull. The above table is somewhat indefinite. For the writer's own use he has elaborated the table to some extent: very bright, an unclouded sun casting a dense, sharply defined shadow; bright, sun slightly obscured, casting a clear shadow but not very dense; mean, a very faint shadow; dull, a clouded sky, showing no shadow but landscape clearly distinct; very dull, a lowering sky with landscape immersed in gloom. This is not much more tangible, as in either case there is but a shadow to grasp at. In reality, there are so many factors affecting the time of exposure that it is impossible to make any absolute rules; the more so that it depends, in a large measure, upon what is the portion of the landscape of which it is required to obtain a record. One part may be well lighted up, another buried in shadow; here you find densely timbered benches, there light coloured grassy slopes; again, the snow in one part may be in brilliant sunshine, in another in deep shade; at one time you have the sun at your back, at another you look across the shadows, and at a third you photograph right into the sun; the distance may be obscured by deep violet haze, or the whole dimmed by a thin veil of smoke. It is more by good experience, good judgment and good luck that success is obtained than by cut-and-dried rules. In any case the standard rule in landscape-photography holds good: "Expose for the shadows, and let the lights take care of themselves."

Considerable difficulty is experienced in reaching many stations with the instruments, and the best part of the day is frequently taken up in doing so and returning; so that, when at the station, the views must be taken whether the conditions are favourable or not.

It may be laid down as a general principle "give plenty of exposure," and the writer might almost add as a general rule "give the right exposure, and half as much more." From an under-exposed plate but little can be obtained that will be serviceable to plot from. The shadows in the negative are clear glass, giving black blotches, without detail, in the enlargement. What is not there cannot be brought out. On the other hand, an over-exposed plate may, by skilful treatment, be made to yield a fairly good enlarging negative. In fact, a plate exposed twice or even three times too much will still give useful results. In support of the above opinion, the writer may quote the following from a paper written by Mr. B. J. Edwards, of London, in the *Year Book of Photography and Photographic News Almanac for* 1890:—

The golden rule, as well stated by Captain Abney in his paper, to which I have referred, is "always expose long enough." An under-exposed negative is utterly worthless; it is a mistaken idea to suppose that detail can be forced out by excess of ammonia or other alkali; but on the other hand, by modifying the developer, it can be kept back to almost any extent, so much so that it has been said that "there is no such thing as over-exposure." Without going as far as this, it is certainly a fact that a good negative can be made from a plate which has received eight or ten times the normal exposure.

In the present case, the writer cannot say that he agrees with Mr. Edwards to quite this extent. With photographs for plotting, great risk is run of losing the distance by too much exposure and also of fogging the plates by chemical treatment for the same.

The Canadian cameras are oblong in shape, and can be used in what is designated as either the horizontal or vertical position. In the former, the field covers about 57 degrees of arc, and it requires seven views to complete a circuit, making due allowance for overlap. In the latter, about 38 degrees of arc are covered and eleven views required. The vertical position is used to photograph deep valleys immediately below the station, which would otherwise be cut out of the field.


FIG. 4. VIEW FROM [illegible] STATION

It is the exception that a full circuit is completed from one station, nor are stations often found where this can be done with advantage. As the writer has already stated, views cannot always be taken under the best conditions for photographing; when, therefore, a circuit has to be made from one or more stations on a hill, it is wise to commence as near as possible on the right of the sun, without allowing it to shine upon the lens. By the time the last view is reached, the sun will have moved sufficiently to admit of its being taken. Photographs near the direction of the sun require longer exposure. If absolutely necessary, a view may be taken directly under the sun by cutting off the rays from the lens. In such a case, at least four times the exposure authorized by the stage of light is required.

The orientation-point of a view is the point selected from which to obtain the direction of the distance and horizon-lines and enable their traces to be laid down on the map for plotting purposes. The azimuth of this point is obtained by an angular reading, from some convenient primary or secondary signal of the triangulation. If the position of some such signal-point can be identified in the photograph, and there is no doubt as to its recognition, it serves the purpose of an orientation-point and no other need be located. For the above purpose a 3 inches transit-theodolite, specially built by Messrs. Troughton and Simms, of London, is used. It is set on the same tripod as the camera, and is conveniently arranged for carrying.*

It is advisable to have at least two orientation-points in each view, in case of one failing to come out clearly in the development of and enlarging from the negative. Failure to identify an orientation-point renders an enlargement useless for plotting.

Difficulty is frequently experienced in selecting suitable points. It is of the first importance that those selected should be certain of recognition. Great care should be taken that the points chosen are suitable for identification; a point may be visible in the negative, and yet not appear in the enlargement. It is not wise to accept objects at a great distance, unless clear and very sharply defined. Distance, as a rule, requires less exposure than the nearer parts of the landscape and consequently

* *Photographic Surveying*, by Mr. E. Deville, pages 138 and 139.

the points, if too distant, may be lost in exposing for the portion of the view required for the plot. The top of an isolated or comparatively isolated tree, a sharp pointed hill, a nose or peak of rock, the gable of a house or corral, a snow-spot and sometimes the corner of a pond are good objects. Sticks, stones, trees in the mass, rounded hills and distant mountain-points, although enticing, are very uncertain. Seen through the telescope, an object looks large, but on the plotting-photographs the same object can be obscured by the point of a needle. A rough pencil-sketch added to the camera and transit-notes will materially assist identification.

FIG. 5.—SIGNAL AT A PRIMARY TRIANGULATION-STATION.

In the notes, the hour of the day, stage of light, time of exposure, limits, and general character of the view are entered; also a few remarks as to the kind and relative quantities of timber in each view, thus enabling an efficient timber-map to be made.

A small dark tent is used for changing and marking plates. It is not advisable to use it until after dark or in deep twilight. If used in bright sunshine, plates may be fogged. A ruby lamp renders changing at night easy, although doing so in the dark is preferable and merely a matter of practice. By a simple con-

trivance of snaps and rings, the dark tent can be hung within another tent in a very short time, and so avoid the disturbing element of wind.

It must not be supposed that a simple collection of photographic views and transit-readings, as described above, is all that is necessary to furnish data for a topographical map. On the contrary, it is only the mechanical portion of the work. To succeed, the operator must be by nature and training a good topographer, with a cast-iron constitution. He must have the knack of finding his way like an Indian; nothing should escape his observation that will tend to an accurate delineation of the country. He must impress upon his memory and be able to recall the panorama seen from every photographic station; doubtful parts must be explored, and stations selected to give the best possible view. He must bear in mind that every part has to be seen from at least two points, sufficiently far apart and so placed that they will give a good base for plotting. It has been said that the mapping can only be done by the surveyor who does the field-work; while the writer does not hold with this view entirely, there is no doubt that a better, more artistic and more accurate map can be turned out, provided the surveyor has the necessary attainments as a draughtsman. Unfortunately men who are equally adapted to field and office-work are few and far between. By taking certain precautions with the field-work, (such as indicating the triangulation and orientation-points upon the photographs and furnishing a plan of the triangulation-points and camera-stations, together with the direction of the limiting lines of each view), the writer believes that the work may be handed over to a good topographical draughtsman, who, provided he has had some experience of the field-work, can turn out a fair representation of the area surveyed; but, at the same time, it will probably lack much of the vim and accuracy of detail that can only be obtained from an intimate personal knowledge.

*Office Work.*—The developing and enlarging of the photographs and plotting of the map do not fall within the scope of this paper, but a few words may not be amiss. Any professional photographer can develop the plates and enlarge from the negatives, more or less successfully. To obtain the needful results,

however, it is desirable that the surveyor should be trained to do the work himself. He then knows what portion of the view to develop and when enlarging, what parts to bring out most clearly.

Mr. E. Deville in his book goes carefully into the subject of developing and enlarging, and the writer can say from experiment that his instructions, based upon the best scientific investigations, if carefully followed, will give good results.

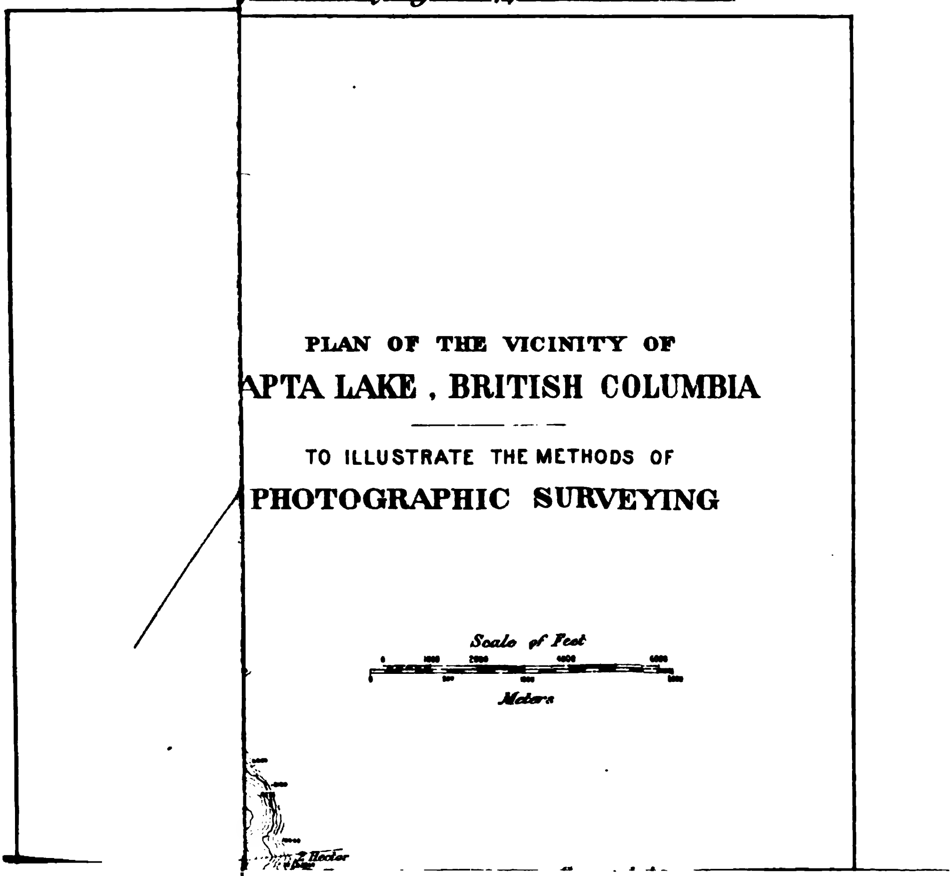
On Canadian surveys, most of the enlarging is done during the winter months, when daylight is short and uncertain. To obviate the difficulty, a 50 candlepower electric lamp is used with

FIG. 6. SIGNAL AT A CAMERA-STATION.

the enlarging camera described in Mr. Deville's *Photographic Surveying*,* and gives a steady, uniform light. The highest density of the negative may be measured by the photometer, and the time of exposure deduced from such measurement. A little practice soon enables the operator to judge the necessary exposure the moment that the view is thrown upon the screen. By skilful shading of the thin portions of the negative, the denser parts are given sufficient exposure without blotting out the weaker ones and a uniform print is obtained.

* Page 193.

"To illus phic Surveying as applied in Canada."



Plotting the contours and drawing the map generally is the most tedious stage of the method. The time required depends to a large extent upon the scale employed and the character of the country. Mountain-regions, where the features—ridges and valleys—are massive, can be more rapidly delineated than foot-hill country, which is more broken in character and not so well defined in contour.

The scale upon which the Canadian surveys have been mapped is as follows:—Rocky Mountain's survey, $\frac{1}{20,000}$; Alberta Watershed and Crow's Nest survey, $\frac{1}{30,000}$; Alaska surveys, $\frac{1}{80,000}$. The larger the scale the greater is the detail required for the drawing. The office-work occupies at least twice the time of the field-work. To offset this the field-work can be accomplished in half the time required for any other method.

The writer appends the following illustrations:—

(1) Certain map-issues from the Canadian Surveys named. While these will serve to show the uses to which the method has been put, they must not be considered as topographical map-specimens.

(2) A sample of contouring and photographic enlargements from which the plot has been made.

(3) Prints from negatives used for enlargements in No. 2 above.

(4) Enlarged copies of plates placed at the end of Mr. Deville's book on *Photographic Surveying*, showing a number of perspective constructions (Figs. 1, 2, 3 and 4, and Plate XIV.).

(5) Plates showing signals used at triangulation and camera-stations (Figs. 5 and 6).

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The CHAIRMAN (Mr. H. C. Peake), in moving a vote of thanks to the writer for his most interesting paper, said that the methods described could be practically adopted in this country, and there were many members in foreign countries who would obtain much useful information from the paper.

Mr. BENNETT H. BROUGH (London) said that Mr. Wheeler's paper formed a valuable addition to the *Transactions*, and indicated the excellent surveying work that was being carried on in British

colonies. The writer, however, underrated the value of photographic surveying to engineers, and the method was specially adapted for such topographical surveys as mining engineers were sometimes called upon to execute. In a treatise on *Mine Surveying*, which he (Mr. Brough) had published, some illustrations were given of the successful application of photography to the survey of mining properties in Mexico, in the Carrara marble district of Italy, in the Styrian iron-ore mines, and in the Klondyke gold-fields. The rapidity with which the field-work was carried out was a conspicuous advantage in unhealthy malarial districts, which a mine-surveyor was often called upon to survey, and the calculations could be completed elsewhere. The results were more accurate than those obtained with the compass or plane-table, and the photographs recording the survey often supplied information of value as an addendum to mine-reports. While it was gratifying to see what was being done in the colonies in this way, it was to be regretted that attention was not drawn to what was being done at home, for as a matter of fact one of the most convenient, compact and accurate instruments for carrying out photographic surveys was the invention of an Englishman—Mr. Bridges-Lee. That gentleman's camera-theodolite was certainly a much more ingenious one than the Austrian or American instruments.

Mr. L. G. Carpenter (Fort Collins, Colorado, U.S.A.) wrote that Mr. Wheeler's paper on photography as applied to field-work in Canada, suggested the difficulties that arise in field-work and in the reduction of photographs. He had been much interested in the work of the Canadian Survey in their adaptation of photography to an accented country, and he had kept somewhat in touch for a number of years with their work. The skill used in the photographical part of their work had been excellent, and the difficulties experienced in obtaining clear photographs had been admirably met.

Throughout the Rocky Mountain region of the United States as well as Canada are vast areas with sharp outlines. Located as they are at a high elevation, with a winter lasting throughout a large part of the year, any method by which the work of the field can be shortened or whereby a large amount of work can be performed in a short space of time is almost an absolute necessity. In carrying

on topographical surveying, it is a justifiable expense, and photography, by its record, demonstrates its adaptability for this purpose in such a country. The difficulties in narrow gorges and deep cañons are so great that it would seem that it must be used in connection with other notes, but in regions where valleys are relatively open, where the points are well marked and can be identified, it would seem that the system has no superior, considering the time and expense. The Canadian Survey had admirably applied the system and skilfully met the difficulties of photography at high elevations, and of peaks at long distances. Usually the photographs under such conditions are of little value.

In a country of gentle slopes and rounded outlines with relatively small differences in elevation, it would not seem to the writer that the method would be useful, because of the uncertainty of locating the points on different photographs. It is possible that by skilful choice of the hour, so as to make use of the shadows and thus bring relief, it could still be used with some degree of success in such a country. Such a use would also be desirable in a country so broken as the Rocky Mountain region. The method is also useful in making a minor survey in elevated regions. He (Mr. Carpenter) did not think it would compare in accuracy with an ordinary transit-survey. In cases, where for any reason it is necessary to do the field-work in a short space of time, he would not hesitate to use the photographic method even on such surveys as the survey of a reservoir. There are, in the Rocky Mountain region, many sections where the photographic method would be the cheapest and sufficiently accurate for that purpose.

Colonel A. LAUSSEDAT (Paris) wrote that he had read with pleasure and attention, Mr. Arthur O. Wheeler's paper on photographic surveying as it is practised in Canada. He could not add under any conditions to that writer's very clear and equally exhaustive paper, and he thought that the Institution would do service to the members by printing in the *Transactions* the valuable account of facts contained in Mr. Wheeler's note, accompanied by judicious reflections and hints. Moreover, since the work of Mr. Deville can be readily purchased, it will be easy for the members to see the care with which the question of the application of photography to surveying has been treated in Canada, and from the maps which have been published by the Canadian Survey, the

members have a still greater assurance of the very great importance of a method, which economizes both time and expense and gives results of as high a degree of exactitude as could be desired, whilst leaving in the hands of the operators, and in case of need in those of people charged to control other work, the most valuable documents constituted by the views photographed upon the spot themselves. The reflections and recommendations are most important,* and should be noted by all those who wish to work seriously at photographic surveying. They may be compared with those presented by Mr. Deville in his preface.† Finally, it must be well understood that in commencing to apply the method the operations must be entrusted to topographers of great skill and intelligence.

Mr. JAMES McEVOY (Fernie, British Columbia) wrote that he had never used the photographic method for topography, and his appreciation of Mr. Wheeler's paper was due to experience in an entirely different system of topographical surveying. Mr. Wheeler's paper bears the stamp of the thoroughly practical and energetic topographer. The supplementary use of traverse-lines along the bottom of valleys described by him is a most important improvement in the method. These might with advantage be more frequently used than has hitherto been the practice. The tediousness of plotting is undoubtedly the weakest point in the system. Delays caused by smoky atmosphere (not too dense to prevent other methods of work) are sometimes rather serious. The system is very well adapted to the construction of maps of a scale of 1 mile to 1 inch or smaller, but for a larger scale and for contours closer than 100 feet of vertical interval it seemed to him, although expressed with some hesitation, that actual measurements on the ground would be preferable.

Mr. M. H. MILLS (Mansfield), in seconding the vote of thanks, said that he lately had been making examination of ironstone properties in the Asturiās in Spain, and he there met a Spanish surveyor who employed an apparatus similar to the one described in Mr. Wheeler's paper but without a camera. It was a sort of range-finder, and he was quite sure that the surveys necessary could not have been made in the ordinary manner without its use. More careful thought of this description of work would no doubt

* *Trans. Inst. M.E.*, 1901, vol. xxi., page 433.

† *Photographic Surveying*, page vi.

be of great value to them as mining engineers, not perhaps so much at home as abroad, both on the Continent and in our colonies.

The vote of thanks was warmly adopted.

Mr. A. O. WHEELER wrote that the kindly reception of his paper by the members had caused him very great pleasure. Referring to the discussion thereon and Mr. Bennett H. Brough's remarks, he might say that it was not his intention to underrate the value of photographic surveying to engineers; his having unintentionally done so was due to lack of knowledge on his part of its utility in this respect. He was well acquainted with Mr. Bridges-Lee's camera-theodolite, and it had not so far been tried in our photographic surveys owing to the fact that it had not been introduced when our surveys were commenced, and the apparatus then employed filled the requirements and had not since been changed.

The difficulties referred to by Mr. L. G. Carpenter in narrow gorges and deep cañons necessitate the employment of subsidiary traverses. In a country of gentle slopes and rounded outlines with relatively small differences in elevation, the method applies but poorly. Here, however, other methods are easy of application. The degree of accuracy depends upon the number and closeness of the camera-stations and the precision with which these stations are fixed in position. Photographic methods can be utilized, where transit surveys would be out of the question.

Referring to Mr. McEvoy's remarks, it may be said that while the plotting is the most laborious and slowest part of the work, it is more than compensated by the rapidity of the field-work, and the few required in the office as compared with a large party in the field. The chief effect of smoky atmosphere is to shorten the range; this applies to any other method that can be used in a country where photographic surveying is most effective. Any scale may be employed, the larger it is, the more laborious becomes the office-work. Most of the Canadian surveys have been plotted upon a scale of $\frac{1}{20,000}$ and $\frac{1}{30,000}$; but have been reduced in map publication. Contour-equidistances may be shown as readily at 10 feet as at 100 feet, it merely means a larger number of camera-stations. In areas where photography is best applied, actual measurement on the ground would be impossible, or so costly as to be prohibitive.

# THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON, MAY 24TH, 1901.

MR. H. C. PEAKE, PAST-PRESIDENT, IN THE CHAIR.

## DISCUSSION OF MR. THOMAS WARD'S PAPER ON "THE SUBSIDENCES IN AND AROUND THE TOWN OF NORTHWICH IN CHESHIRE."*

Mr. THOMAS DOUGLAS (Darlington) said that he confessed ignorance as to the particular subsidences about Northwich, but he supposed that they could not by any mathematical calculations arrive at any indication as to the amount of support which it was necessary to leave for protecting the surface, or the buildings on the surface. He had unfortunately had a considerable experience in reference to the payment for damage caused by subsidences, and he had endeavoured to find some theory as to what should be done to support buildings under which there were mine-workings. Trusting rather to his own experience he had come to the conclusion that it was almost better to remove all the mineral from under the buildings and to take the risk of compensation for possible damages.

Mr. J. S. DIXON (Bothwell) said that the salt-beds in Cheshire were as much as 90 feet thick and not very far below the surface, and it was not astonishing that the results were so disastrous. The author raised one point which coincided with his own experience and that of others, namely, that so long as salt was being eaten away by denudation, by water flowing over the top of the seam, the subsidences took place very gradually, and little or no damage was done to the buildings, but when the water was allowed access to old pillars and old workings, these dissolved and collapsed with the results shewn in the paper. Mr. T. Douglas

* *Trans. Inst. M.E.*, 1900, vol. xix., page 241.

had alluded to an important subject upon which there had been valuable papers in the *Transactions*. He had worked 20 feet of coal, under a town, in four different seams, and he found that if it was all swept out quickly, either by the longwall or the pillar-and-stall method there was not very much damage done. It was where the workings ceased that the break from the surface took place, or if the regular advance of the workings was delayed from any cause. If the buildings stood above the middle of mine-workings at a depth of 600 feet the damage was inconsiderable, compared with the value of the coal which would have to be left to support the property.

Mr. THOMAS WARD (Northwich) wrote that, in answer to Mr. Thomas Douglas, he might state that the pillars left in the top mines, 15 feet square, were considered sufficient to support the roof of the mine in the lower bed of salt, but experience proved them to be insufficient, and when they began to crush, pillars, 24 feet, 30 feet and even 36 feet square, were left, and these have proved strong enough, as there have been no surface-sinkings over the mines with the stronger pillars. He was not aware of any mathematical calculations that had been made, as he did not think any one had entered into the matter with sufficient knowledge of all the facts to make such calculations of any value. No allowance for buildings on the surface had been made in any of the mines that are worked under portions of Northwich, nor did he know of any instances where subsidences and damage to property had arisen from too weak pillaring in any of the mines worked under the town.

Even in the top mines, as explained in his paper, it was doubtful whether subsidences occurred, except when water found its way down the shafts and into the mine, though the pillars left in some cases would lead him to suspect with his present knowledge that possibly such sinking may have occurred.

The salt-miners of a century ago believed that the mines would not collapse even if no pillars were left, but when from 15 to 30 or more feet of mineral is removed, and no support left, serious sinking must inevitably occur.

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Mr. H. BIGG-WITHER read the following "Notes on Detonators":—

# NOTES ON DETONATORS.

By H. BIGG-WITHER.

In bringing this subject before the members it is not the writer's intention to deal with it in any but a practical manner, as the scientific aspects can easily be learnt from text-books. Owing to the rapid extension of the use of detonating explosives in mines, the writer feels sure that it will be to the advantage of members to learn as much as they can about the detonator, which is a necessary adjunct to the use of such explosives.

The ordinary detonator of commerce consists of a copper shell, usually containing a mixture of fulminate of mercury and chlorate of potash; but the proportion of these two ingredients varies considerably, as will be seen by the following analyses, recording the percentages of chlorate of potash:—(A) 5, (B) 22·19, (C) 24·93, (D) 31·57, (E) 34·18, and (F) 39·8.

In August, 1897, the following circular was issued by H.M. inspectors of explosives:—

In consequence of several fatal accidents, which have occurred this year through charges of explosives of the nitro-compound class being improperly exploded, and which, in some cases, were clearly traceable to the use of detonators of insufficient strength, H.M. inspectors consider it advisable to call your attention to the accompanying table of standard charges for detonators (see *Dictionary of Explosives*), and to inform you that this scale is the only one officially recognized and generally accepted. Accordingly, if any detonators are issued which do not come up to this standard, a serious responsibility will rest upon the manufacturers or importers of such detonators, in the event of any accident occurring through persons being misled in regard to the strength of the detonators supplied to them.

*Standard of Detonators.*—The charge to consist of a mixture of fulminate of mercury 80 per cent., and chlorate of potash 20 per cent., or of some other explosive mixture of the fifth (fulminate) class of not less strength than the above.

The power of detonators is indicated by various numbers, as follows:—

| | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. | No. 6. | No. 6½. | No. 7. | No. 8 |
|---|---|---|---|---|---|---|---|---|---|
| Charge per 1,000, in grammes ... | 300 | 400 | 540 | 650 | 800 | 1,000 | 1,250 | 1,500 | 2,000 |
| Individual charge, in grains ... ... | 4·6 | 6·2 | 8·3 | 10 | 12·3 | 15·4 | 19·2 | 23·1 | 30·9 |

This circular, which stipulated a minimum standard of composition, had the effect of removing from the market all lower grades of detonators, and the detonators now in use vary from this minimum up to a maximum strength of 95 per cent. of fulminate of mercury and 5 per cent. of chlorate of potash. The mining engineer naturally uses whatever power of detonator is recommended by makers of any particular explosive, while the

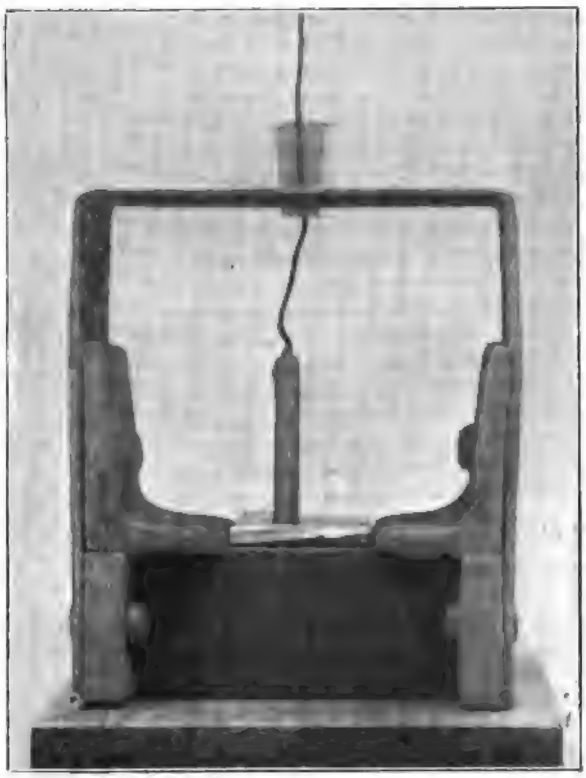

FIG. 4.—VIEW OF APPARATUS FOR TESTING DETONATORS. ABOUT HALF SIZE.

maker recommends a power which has a sufficient margin of strength to ensure perfect detonation under all probable conditions. This is a most important consideration. The mining engineer puts these detonators into use, believing as he has every right to believe, that they are sufficient to detonate the particular explosive that he uses; and whenever the detonator is heard to explode and the explosive is not detonated, the explosive

is at once blamed as being defective. This sweeping condemnation of the explosive arises from the fact that we have hitherto known so little about the detonator, or of the causes which may render a detonator of a given number unreliable for detonating purposes. The writer proposes to describe some of his experiences in this matter, to endeavour to make the members acquainted with some causes, and to explain some of the methods of testing for defects in so important an adjunct to modern mining explosives.

It is almost impossible to prove that the detonator in individual cases is the cause of failure; whether the explosive is detonated or not, the detonator no longer exists, and absolute proof that the failure was caused by it is impossible. It is, however, sometimes possible to prove the defect inferentially, by getting hold of the explosive and trying to fire it with a detonator of equal power, or, preferably, of lower power. But even here one is met by the difficulty that the cartridge is no longer in the same condition as when the failure occurred, for the imperfect explosion has split the cartridge open, and, more often than not, the explosive when recovered has become damp by exposure or is mixed with dirt. In the course of the writer's experience he had many times investigated himself or by men working under his orders, individual failures where the detonator had been heard to explode but had not detonated the explosive; and the fact that the explosion of the detonator was clearly heard induced one to assume that the fault lay either with the explosive or with its manipulation. This latter view was often supported by the fact that the explosive, which had failed, was afterwards fired by a detonator of weaker power.

In investigating a case last year, where both explosive and detonators had been changed, ignitions improved for a few days until failures again occurred. When the cause was discovered, it appeared that the men, who were contractors and used ordinary plain detonators, were in the habit of placing sawdust (gathered from the carpenter's shop) into the boxes used to carry the detonators, and from this cause they became damp. In order to confirm this opinion, Mr. W. J. Orsman placed damp sawdust in a bottle, laid a few detonators upon it, and closed the bottle. After 24

hours, the detonators had absorbed 0·1 per cent. of moisture; after 14 days, 0·4 per cent.; and after 22 days, 0·5 per cent. After 40 hours' exposure to the damp atmosphere produced in the bottle by the moist sawdust, the detonators failed to fire the explosive,

A A

B B

C C

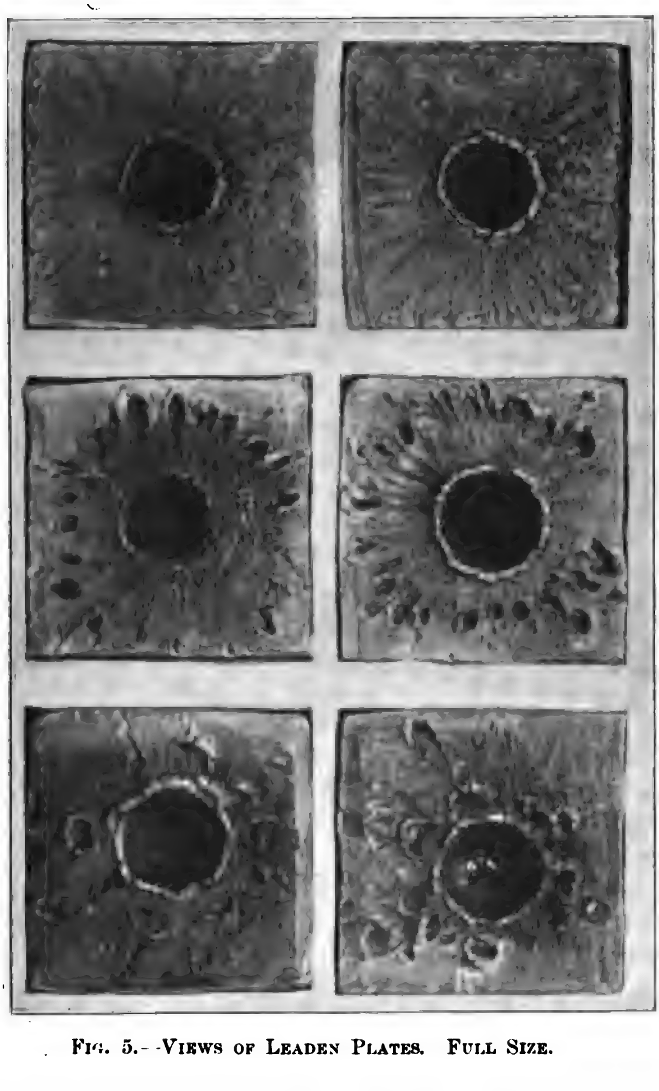

FIG. 5.—VIEWS OF LEADEN PLATES. FULL SIZE.

although exploding themselves. The same explosive was readily exploded afterwards by a dry detonator of less power.

The writer has gone into this case in some detail because he

wished to impress upon the members as strongly as he could how essential it was that detonators should always be stored in a dry place, and to indicate that trivial circumstances may upset all previous care. The same remark also applies to explosives, as their greatest enemy, as a rule, is moisture.

As already mentioned it is difficult to test the detonator and to obtain a direct record of its quality. In the course of his investigations the writer has adopted an apparatus, in use in Germany, which met this essential requirement. The apparatus (Figs. 1, 2 and 3, Plate XV.) for testing detonators, namely, their explosive effect (their power is tested in another way) consists of a metal frame and a plate of pure (soft) lead. The leaden plate is placed in its proper position (Fig. 4), the detonator simply stands on it in the centre, and is balanced by the fuse or electric wire (with a plug) passing through the hole in the top. The test-plates are of two thicknesses, namely:—3 millimetres for No. 1 to No. 3 sizes, and 5 millimetres for No. 4 to No. 8 sizes of detonators.

The writer has made a number of experiments with leaden plates, 5 millimetres thick. The leaden plates, A, shewn in Fig. 5, are typical of a good detonator. The detonating-effect is not so much shown by the punctures as by the fine radiating marks on the surface of the plates. The fine markings show that the force of the explosive smashed the copper tube to powder, some of which is often found adhering to the sides of the plates.

The leaden plates, B, shewn in Fig. 5, are marked with fine radiating lines round the centre, but with heavier markings outside. This difference of marking is probably due to the upper portion of the fulminate not being detonated, while the lower portion was detonated. These particular detonators, in spite of being defective, would have detonated the explosive, thus proving the advantage of using a detonator of higher power than is actually requisite.

The leaden plates, C (Fig. 5), although punctured in the same manner as a good plate, are marked with large indentations and no fine lines, showing that the copper tubes, instead of being blown to powder, were ripped into pieces by a much slower explosion, namely, an explosion which might or might not have set up a detonating wave.

In other leaden plates, D (Fig. 6), although the holes are deep and larger than with a good detonator, the plates are unpunctured and have heavy markings only. In these cases, also, it is difficult to say whether the explosive would have been detonated or not: it might detonate but not with full effect.

D D

E E

$F_1$ $F_2$

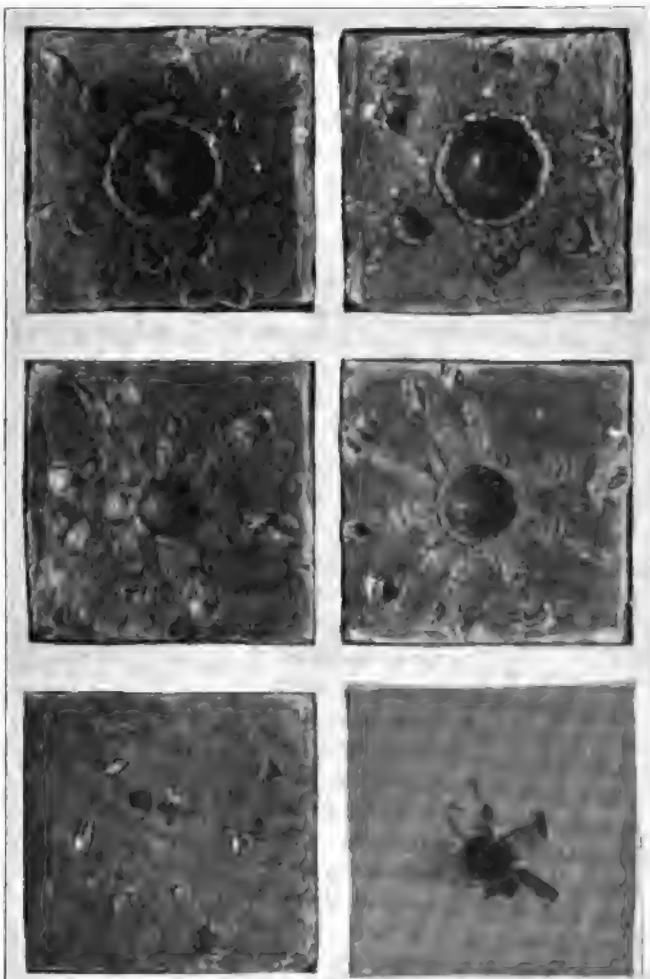

Fig. 6.—Views of Leaden Plates. Full Size.

The leaden plates, E (Fig. 6), show still less power. The plates are not punctured and the marking on them almost pictures the copper tube being opened out in long strips. These detonators

certainly would not have set up a detonating wave in the explosive.

The leaden plate, $F_1$ (Fig. 6), a very rare specimen produced by a very damp detonator, actually shows how the slow explosion rips open the copper tube instead of shattering it; and it also affords a key to the correct reading of the preceding plates. $F_2$ shows a ripped tube produced by slow explosion.

These plates (Figs. 5 and 6) may be taken as giving a direct pictorial record of the efficiency of individual detonators, but unfortunately they do not record the report of the explosion, which is essential to the writer's argument, namely, that because the detonator had been heard to explode without the explosive firing, it by no means follows that the explosive was at fault. As a matter of fact, the explosions on the leaden plates, B, C and D, were quite as loud as the report from the explosion of a good detonator, A. After a little practice the ear becomes accustomed, and one can distinguish between the reports, the report of A being sharp, while B, C and especially D, seem to give a fuller volume of sound, due, no doubt, to the slower action.

The writer has only touched upon moisture as a cause of defects in detonators, there may be other causes, but the one here named more particularly concerns the mining engineer, who can do much to keep explosives in good condition. It is of no use for the manufacturer to take elaborate precautions to ensure delivery of an explosive in perfect condition, if the mine officials do not take proper measures to see that it is stored in a dry magazine, and unless (instead of being allowed to lie in stores a long time) care is taken that it is used up in the order in which it is received.

In conclusion, the writer believes that he has brought something new before the members, and something which may tend to reduce in the future the number of missed shots.

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Mr. C. C. Leach said that if there was danger from detonators owing to their not being sufficiently strong, all weak classes of detonators should be discarded,

*The Institution of Mining Engineers.*
*Transactions 1900-1901*

VOL. XXI. PLATE XV.

**To illustrate Mr. H. Bigg-Wither's "Notes on Detonators."**

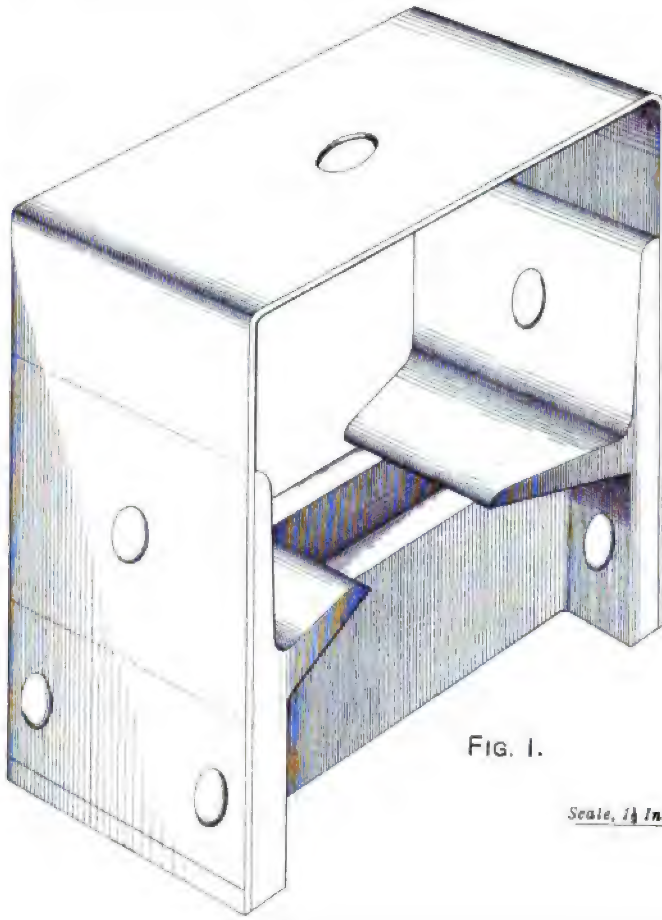

FIG. 1.

Scale, 1½ Inches to 1 Inch.

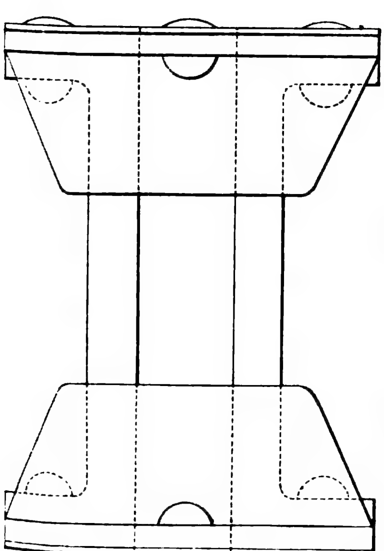

FIG. 2.—PLAN WITH TOP REMOVED.

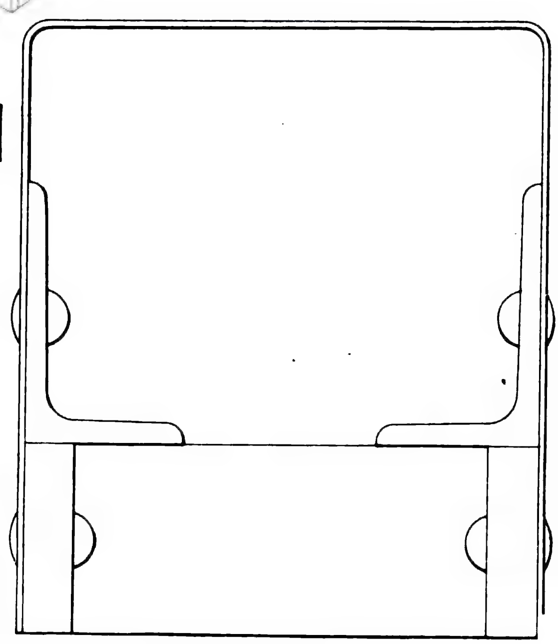

FIG. 3.—

Mr. H. Bigg-Wither said that they might have a strong detonator which would not detonate, owing to its having become damp.

The Chairman (Mr. H. C. Peake) said that before he heard this paper he wondered what anyone could find to say about detonators that would be of any benefit, but he was very pleased indeed to have heard the paper read to-day. He always liked to know the specialist's view on any subject, and he was sure if they took warning by the facts given in the paper they would have far fewer shots missing fire with high explosives. They were very much indebted to the writer of the paper, and he moved that a hearty vote of thanks be accorded to him.

Mr. Uriah Dudley (Cue, Western Australia) asked whether Mr. Bigg-Wither had found sometimes with weak or low-power detonators that they failed to detonate certain high explosives, but set fire to and burned up the explosive; and also whether he could point out any test that would certainly indicate this point or power of the detonator. In the absence of other lengthy and expensive tests of all individual detonators and explosives he had, in cases of practical failures, the causes of which seemed obscure, devised and made tests as follows:—He laid on the ground a number of plugs of the explosive in a straight line, end to end, as close as possible, the last plug containing the detonator in the usual way, and it was then fired. The number of plugs completely detonated (sometimes 12 and even up to 20 plugs) showed at once a relative and register value. Variations of this test are easily devised to test readily any detonator, and though not exact it has some practical value and importance; this test was suggested from the fact that long holes carrying a great depth and many plugs of explosive have at times shown some unexploded plugs, and these were always the bottom plugs, when the detonator was placed on the top one.

Mr. H. Bigg-Wither said that he had never reached that point; in his experiments, when there was no detonation, the explosive remained intact.

Mr. M. Walton Brown (Newcastle-upon-Tyne) stated that he had manufactured an explosive, which ignited without detonation; when using a low-grade detonator, it simply burned slowly in the shot-hole.

Mr. H. BIGG-WITHER said that was quite possible, and might happen with certain explosives, though, as a manufacturer of explosives, he would not name them.

Mr. URIAH DUDLEY said he did not know whether to attribute the defective ignition to the detonator or to the explosive, but he had refused to allow detonators to go into the mine, without having tested every box. In the Colonies, where so many brands of detonators and explosives were offered, this was a very necessary precaution.

Mr. H. BIGG-WITHER said that the paper was purely a practical one, and he hoped that Mr. Orsman would write a more definitely technical paper, at a later date.

Mr. S. F. WALKER asked whether it was not possible to get to "dead rock" in this matter. It occurred to him that the probabilities were very much with regard to an explosive the same as with gas. Gas could not be fired unless there was a certain minimum of heat delivered in a minimum quantity of time. If the minimum quantity of heat could be determined for each kind of explosive and the minimum time (it would be a small fraction of a second) they would have good grounds to go upon. The heat must be absolutely free to be delivered to the explosive.

Mr. HENRY PALMER (Consett) asked whether in the author's opinion it was due to detonators being cheaper, or was there any other reason why less powerful detonators were used. He agreed with Mr. Leach that if possible they should eliminate the weaker kinds, and there would then be less risk of non-effective shots.

Mr. H. BIGG-WITHER remarked that manufacturers of explosives recommended the detonator which had a sufficient margin of strength to ensure perfect detonation under all circumstances. They generally advocated the use of a higher rather than the minimum detonator.

A vote of thanks was moved and cordially adopted, and was briefly acknowledged by the writer of the paper.

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Mr. S. F. WALKER read Part I. of his paper on "Alternating Currents and their Possible Application to Mining Operations" as follows*:—

* This paper was read at a general meeting held on June 14th, 1900.

# ALTERNATING CURRENTS AND THEIR POSSIBLE APPLICATION TO MINING OPERATIONS.

## PART I.

## WHAT AN ALTERNATING CURRENT IS.

BY SYDNEY F. WALKER.

### I.—INTRODUCTION.

Mining engineers are now thoroughly conversant with the principal properties of continuous currents of electricity, and their application to mining work, as instanced in the matter of electric bells, dynamos, motors, arc-lamps and incandescent lamps, etc.; but the writer believes that very little has been done in mining work, with alternating currents in this country, and that very little matter dealing with them is to be found in any of the *Transactions* of the institutes specially devoted to mining work. He hopes, therefore, that the information given in the following pages may be of service.*

The engineer who approaches the study of alternating currents of electricity, for the first time, finds very much that is very puzzling, and very much that apparently contradicts all that he has learnt with reference to continuous currents. If he was ever so unwise as to believe that all calculations connected with electrical apparatus can be done on the back of a postage-stamp, he will now have a rude awakening.

He will find that he has at least two distinct sets of phenomena to deal with, where before he had only one, and apparently with the same conditions present, namely, he has to deal, as before, with the fact that he must provide currents of greater, or less strength according to the work which the currents have to perform, whatever that work may be, and he has at the same time to deal with the fact that the strength of each current is constantly changing and executing a very wide series of changes many times in each

* Since this paper was written, in 1900, a number of installations of polyphase alternating-current electrical apparatus have been erected, and many more are in progress.

second. Further, this latter phenomenon brings him the additional trouble, that opposing forces are created within the conductors he provides for the passage of the currents that are to perform the work which he has in hand, so that often the actual energy transmitted and used is considerably less than would rule with the ordinary measurements of continuous currents.

He will find that whereas with continuous currents, the product of the electromotive force and current passing between any two points at any instant measures the quantity of energy he is transmitting, or transforming from electricity to some other form, with alternating currents, the two (electromotive force and current) are often not acting together, and so he has to bring another factor into the equation before he is able to measure the actual amount of energy that he is utilizing.

He will find himself obliged to deal with and provide paths for currents that are apparently useless, in the sense that they do no portion of the work that he requires them to do; and still more strange, although he provides apparatus for generating them and apparently they are generated, yet it is sometimes contended that they are not generated.

He will find also that induction, which he has heard of, when dealing with continuous currents, as the friend to which he owes the generation of these currents, but as not troubling him further, once this generation is accomplished, now meets him at every step, sometimes as a friend, at others as a troublesome phenomenon that has to be allowed for.

In the matter of magnetism also: whereas, with continuous currents all that has been necessary has been to provide a certain quantity of iron, of a certain form, arranged in a certain manner, to direct the magnetism through the conductors on the revolving armatures of the dynamos; and though he has known that a certain loss occurred in the iron cores of the armatures of the dynamo, owing to the generation of heat by reason of the changes of magnetism that are constantly taking place, all that he has been obliged to do in the matter has been to reduce this loss to a minimum by certain structural arrangements, now he finds himself faced by a definite charge for this loss, that he cannot escape, owing to the actual work done by the molecules of iron, when moving in obedience to the rapid changes of the exciting electric currents.

The phenomena of electrostatic charge also, which he has been able entirely to disregard in nearly every apparatus he has dealt with, now steps in and demands attention, sometimes rendering him assistance in a somewhat embarrassing manner.

In the following pages, the writer proposes to explain what an alternating current is, how it differs from a continuous current, and how it comes about that the glow-lamps he buys, marked for a certain voltage, will work equally well on continuous-current or alternating-current circuits provided the marked voltage be present. Also what is meant by providing an alternating current of certain voltage, when the voltage is constantly rising and falling; and what is meant by providing an alternating current of certain strength, when the current-strength is rising and falling constantly during each small fraction of a second of time. He proposes also to explain, how the actual amount of energy delivered to, and required by a circuit using alternating currents, is calculated and measured; and also the phenomena of induction, how they affect the working of alternating-current apparatus, and how their effect is calculated and measured. The writer also proposes to explain what is meant by monophase, diphase and polyphase currents; with their use, and how they operate.

In the first part of the paper, the questions what alternating currents are, how they are measured, and how generated, will be dealt with. In the second part of the paper, the alternating-current motor will be explained; the methods of distributing alternating currents for lighting and power; and the uses to which alternating-current motors have been put.

## II.—What an Alternating Current is.

Alternating currents, as their name implies, are continually changing in direction. That is to say, taking any apparatus, either a generator, a lamp, a motor, cable or any other appliance used in electrical work; with continuous currents, the ethereal or molecular motion which we know as an electric current passes always from one terminal of the apparatus to the other, in the same direction. With alternating currents, this motion passes first from one terminal through the apparatus in one direction to the other terminal, and then from the second terminal through the apparatus in the opposite direction, to the first terminal, these alternations taking place from 25 to 133 times per second, in

modern plant. That is to say, in each apparatus, each terminal or each end is alternately positive and negative 25 to 133 times per second, according to the design.

But this is not the whole difference; in each cycle as it is termed, each complete pair of alternations, both electromotive force and current are constantly changing their values. Each, no matter what the working current may be, is at *zero* twice in each cycle, from which point both electromotive force and current rise gradually to a value considerably in excess of what may be termed the working electromotive force and current, and from that fall gradually to zero; after reaching zero, both electromotive force and current rise again to the same value as previously, but this time, both are in the opposite direction. This is usually shown graphically by the diagram given in Fig. 1, where vertical distances above or below the horizontal line may be taken as the values of either electromotive force or current, at any particular instant, while the horizontal distances from O, at the left side of the diagram, represent successive intervals of time, each complete cycle being represented in time by the length of the horizontal line between three successive zeros. It should be mentioned that individual measurements taken from the curve shown do not represent at the same instant the values of both electromotive forces and currents. Two curves, similar in appearance, are necessary to represent the two values, but the curve shown in Fig. 1, may be taken as a sample of the curve that can be used to represent either.

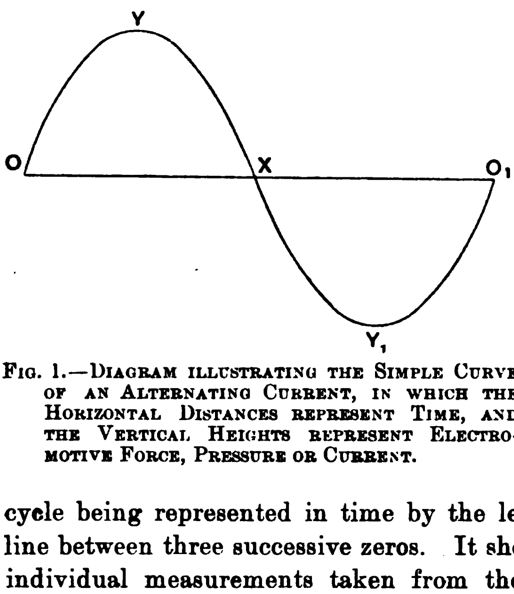


FIG. 1.—DIAGRAM ILLUSTRATING THE SIMPLE CURVE OF AN ALTERNATING CURRENT, IN WHICH THE HORIZONTAL DISTANCES REPRESENT TIME, AND THE VERTICAL HEIGHTS REPRESENT ELECTROMOTIVE FORCE, PRESSURE OR CURRENT.

It will be understood also that the curves shown in Fig. 1, or any similar curve used with alternating currents, do not represent the same thing as the curves known as the characteristic curves of continuous-current dynamos, though they are distinctly

the characteristic curves of alternating currents, and therefore of alternating-current dynamos.

With the characteristic curves of continuous-current dynamos, the variations of the electromotive force of each type of dynamo is shown, as the quantity of current furnished by the dynamo varies. Thus with the series-wound continuous-current dynamo, the electromotive force goes up to a certain point as the current taken from it increases; with the shunt-wound dynamo it decreases; and with the compound-wound dynamo its value remains stationary; and these facts are expressed by the different curves. With the characteristic curve of alternating currents or electromotive forces, the increase or decrease of the working current-strength has nothing whatever to do. The shape of the curve is always approximately the same, though there may be many curves for each individual machine, or particular service.

It may perhaps be as well, before passing on, to explain more fully what is meant by these curves. The characteristic curves of dynamos, like many other curves now so largely employed in engineering work, are graphic representations of physical facts. They enable the engineer to see at a glance how one particular quantity with which he has to deal varies, when another quantity upon which it is dependent varies, and if the curve-diagrams are drawn to scale, they enable him to measure these quantities at any moment, by ordinary drawing-office methods. Where there are two variable quantities, one of which varies in some proportion to the variation of the other, it is usual to express this graphically by drawing two straight lines, as OX and OY in Fig. 2, at right angles to each other, one being an horizontal and the other a vertical line, and to set off the quantities of the independent variable (the one on whose variations the other depends) on the horizontal line, successive increments being usually set off from O to the right, while the quantities representing the dependent variable (the one whose values depend upon the value of the independent variable) as vertical distances above the horizontal line, the horizontal distances being called abscissæ, and the vertical distances ordinates.

A familiar instance of a graphic curve is the ordinary engine indicator-diagram, in which the horizontal distances represent successive portions of the stroke of the piston, and the vertical distances, the steam-pressure at each instant. The curve itself

expresses in a graphic manner, that the steam-pressure inside the cylinder varies at each instant, and at each portion of the stroke after the supply is cut off, while the engineer is able by simple measurements to obtain the actual pressure at any period of the stroke the mean effective pressure during the stroke and the quantity of steam actually taken by the cylinder during the stroke.

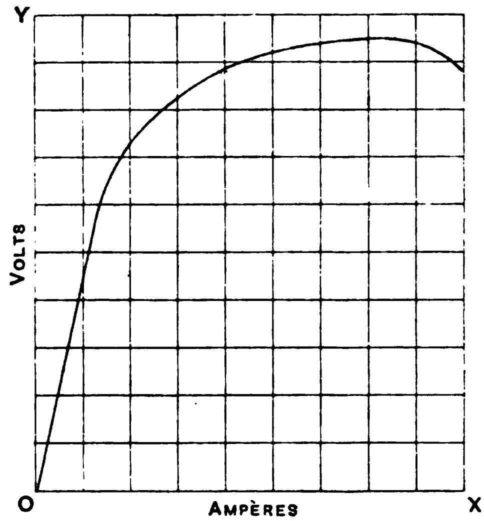


FIG. 2.—CHARACTERISTIC CURVE OF SERIES-WOUND CONTINUOUS-CURRENT DYNAMO.

In the same way, in Figs. 2, 3 and 4, the distances along the line OX represent successive increments of current - strength, while the vertical distances above the line OX represent the electromotive forces generated by the dynamo, at a certain speed, when currents of different strengths are passing to the outer supply circuit; and the curve shows the engineer at a glance (1) how the electromotive forces varies, as more and more current is taken from the dynamo; and (2) the actual electromotive force generated with any given current passing.

The curve also shows him that in the series-wound machine (Fig. 2), the electromotive force is zero, when no current is passing, that it—usually—rises quickly with the first increments of current, and then more slowly; and that after a certain current-strength is reached, the electromotive force declines.

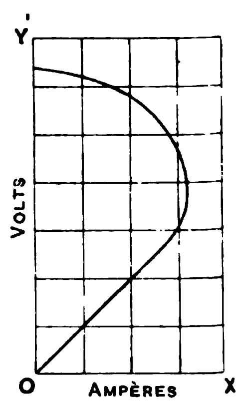


FIG. 3.—CHARACTERISTIC CURVE OF SHUNT-WOUND CONTINUOUS-CURRENT DYNAMO.

In the shunt-wound machine (Fig. 3), the curve shows him that, with no current passing externally to the machine, or, as electricians would say, when running an open circuit, or no load,

the electromotive force is at its highest; that the electromotive force declines gradually as the external current is increased, up to a certain current-strength, and that when this limit is reached, both current and electromotive force decline till, when the machine is on what electricians term "dead-short circuit," it will furnish neither electromotive force nor current.

In the compound-wound machine (Fig. 4), the curve shows him an uniform electromotive force with all currents up to the limit of the proper output of the machine, and it shows him what that limit is.

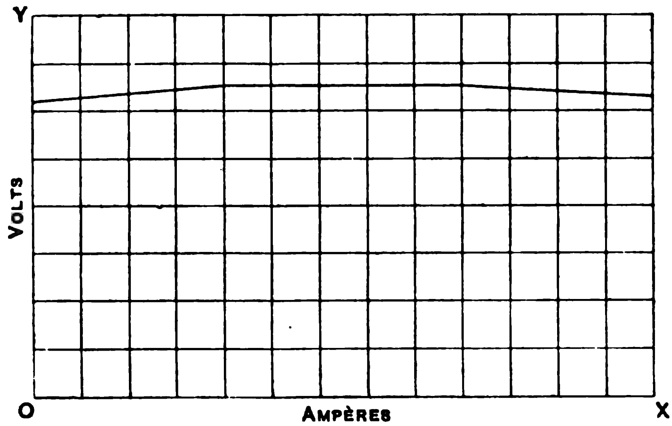


FIG. 4.—CHARACTERISTIC CURVE OF COMPOUND SHUNT-WOUND CONTINUOUS-CURRENT DYNAMO.

With the characteristic curve of the alternating-current machine shown in Fig. 1, successive increments of time are set out on the horizontal line, and corresponding values of either electromotive force or of current-strength are measured by the vertical distances, above and below the horizontal line. In this case, the curve shows the engineer that the electromotive force or current rises very rapidly at first, then more slowly, then falls to zero, as already explained, and goes through the same series of values, but with these quantities of the opposite sign. The curve also enables him to measure the electromotive force or current at any portion of the cycle. The time represented in this case is usually 0·010 second for the whole cycle, or 0·005 second for a half-cycle.* By taking measurements also, of any particular

* In the latest forms of alternating-current machines, 40 periods per second, or 0·025 second for the complete period, has been taken as the standard.

dynamo, whether furnishing continuous or alternating currents, the engineer is enabled to foretell what he may expect from other machines similarly constructed, and also what any particular machine will do under particular conditions.

And now as to how the curve is obtained: The peculiar form of the curve will have been noted. It is what mathematicians call a curve of sines; that is to say, it represents the value of the sine of the angle as it passes from 0 to 360 degrees or through a complete cycle.*

Perhaps a short explanation of the mathematical conception of an angle varying from 0 to 360 degrees had better be given. In Euclid and in the earlier lessons of trigonometry we are accustomed to look upon angles as never being greater than 180 degrees, and usually not greater than 90 degrees; but for many purposes it is convenient to make use of the mathematical convention shown in Fig. 5. If $XYX_1Y_1$ be a circle, $XX_1$ and $YY_1$ diameters at right angles to each other, and OP a radius which may assume successive positions between OX, OY, $OX_1$, $OY_1$ and OX again, which revolves round O as a centre, commencing at the line OX, it will be seen that when OP coincides with the line OX, the angle between the two is 0, when OP coincides with OY, the angle is 90 degrees, the line OP having revolved through a quadrant of the circle; when the line OP arrives at the line $OX_1$ and coincides with $X_1$, it will have passed over two quadrants, or 180 degrees. Similarly when OP coincides with $OY_1$, it will have passed through three quadrants or 270 degrees; and when it again arrives at OX, it will have covered the complete circle, or 360 degrees, from which, if it continues to revolve, the line OP may sweep out successively angles of 450 degrees, 540 degrees and so on. So that in this manner, we may have angles of any value we please; but we need only deal here with angles up to 360 degrees.

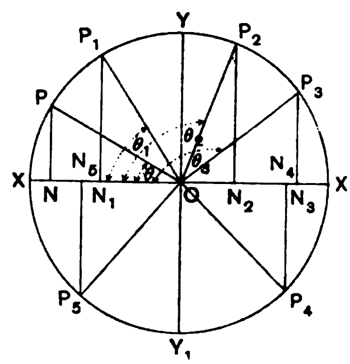


FIG. 5.—DIAGRAM SHOWING THE MATHEMATICAL CONCEPTION OF THE ANGLE FORMED BY THE RADIUS AND THE LINE OF ORIGIN FROM 0 TO 360 DEGREES.

* All alternating-current dynamos do not give a perfect sine-curve.

In using this convention, it is also usual to consider lines drawn to the left of the vertical line OY as plus ( + ), those drawn to the right as minus ( − ); also lines drawn above the horizontal line $XX_1$ as plus ( + ) and those drawn below it as minus ( − ).

Now, if we find that the value of a particular quantity varies as the sine of the angle, and we can trace the values of the sine as the angle passes through the successive values from 0 to 360 degrees, we can thereby trace the variations in the values of the quantity. In most modern alternating-current plant, the electromotive force and the current vary in each complete cycle, very nearly as the value of the sine of the angle varies in passing from 0 to 360 degrees.

From trigonometry, we know that the sine of any angle is the ratio between the perpendicular, the side opposite the angle in question, and the hypothenuse (the side opposite the right angle). If in Fig. 5 we drop perpendiculars from OP, $OP_1$, $OP_2$, $OP_3$, $OP_4$ and $OP_5$, the successive positions of the extremity of the revolving radius, on the horizontal line, we shall have successive values of the sine of the angle which the radius makes in the course of its revolution, in all of which the radius is the denominator: thus, calling the successive angles $\theta$, $\theta_1$, $\theta_2$, and so on, we shall have: —

$$\text{Sin } \theta = \frac{PN}{OP}; \quad \sin \theta_1 = \frac{P_1N_1}{OP_1}; \text{ and } \sin \theta_2 = \frac{P_2N_2}{OP_2}.$$

As the radius is common to all, we may say that the sine of the angle $\theta$ in the successive values which it assumes, is proportional to or varies as the lengths of the perpendiculars, these values being positive when the perpendiculars PN, $P_1N_1$ and $P_2N_2$ are above the horizontal line $XX_1$, and minus when they lie below it.

But if we take a number of successive angles, from 0 to 360 degrees, formed by the radius making one complete revolution, set off the successive lengths of the perpendiculars, allowing equal horizontal distances for successive increments of time, and draw a curved line through their extremities as in Fig. 6, we shall have one form of the curve of sines. It should be noted that the second half of the curve, that which is below the horizontal line and therefore negative, is not drawn exactly below the first half, the reason being that, as horizontal distances represent time, and as the action is supposed to commence with a positive electromotive

force, or current, the second or negative portion of the cycle, being later in time, must be drawn further to the right, must, in fact, commence where the positive half ends. This curve shows us the variation of the electromotive force or the current, furnished by an alternating-current machine, or passing into a circuit using alternating currents, just as the curves in Figs. 2, 3 and 4 show us the variations in the electromotive forces furnished by continuous-current machines, with currents of varying strength passing out from them.

Another way of expressing the fact that the electromotive force and current vary as the sine of the angle through which the radius has passed is as follows:—The value of the electromotive force or current, at any instant during the cycle through which both

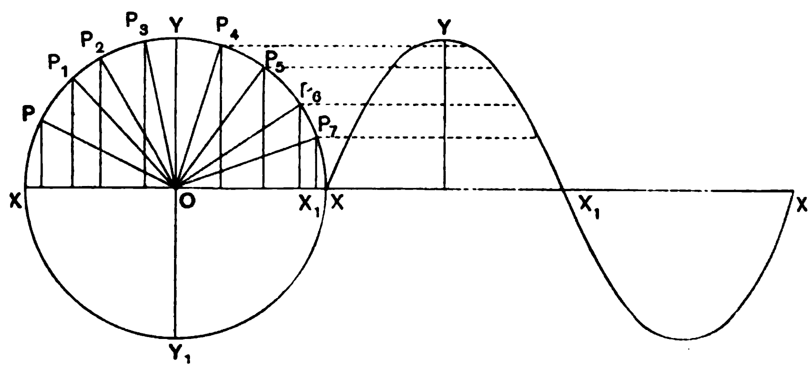


FIG. 6.—DIAGRAM SHOWING HOW THE CURVE OF SINES IS FORMED FROM THE SUCCESSIVE VALUES OF THE SINES, AS THE ANGLE PASSES FROM 0 TO 360 DEGREES.

pass, varies in the same measure as the sine of the angle formed by a radial line, with a horizontal line of origin, as it sweeps out a complete circle, the time occupied by the radial line in passing over the 360 degrees being the time of one period or one cycle of the alternating current, one complete series of alternations; and the times at which the values of the sine are at their maxima, namely, when at 90 degrees and 270 degrees, represent the maxima of the positive and negative values of the electromotive force or current respectively.

Fig. 7 illustrates another method of obtaining the successive values of the sines of the angles, between 0 and 360 degrees. It is known as the Zeuner valve diagram. In Fig. 7, $XYX_1Y_1$ represents the circle as before, swept out by the radius OP. Inside this

circle are two smaller circles, as shown, the radius of each being half that of the larger one, and their two vertical diameters coinciding with, and making up together, the vertical diameter of the larger circle. $OP_1$, $OP_2$, $OP_3$, etc., are successive positions of the radius at angles $\theta_1$, $\theta_2$, $\theta_3$, etc. It will be noticed that each radius is cut off by the smaller circle, at a certain point, the length within the smaller circle getting larger and larger as the angle increases, being 0 at 0 degrees, the full diameter of the small circle or 1 at 90 degrees, 0 at 180 degrees, and so on. These lengths plotted as vertical ordinates, on a horizontal line, to any scale (the horizontal distances representing time), give the characteristic sine-curve of most alternating-current generators.

## III.—Diphase and Triphase or Polyphase Alternating Currents.

It will have been noted that the electromotive force generated by a given alternating-current dynamo, or the alternating current passing in a given circuit, takes a definite time to perform each cycle. It may be 0·04 second, or 0·01 second, but whatever the period be, provided the dynamo be properly constructed, this period is constant and recurring, cycle following cycle in each succeeding fractional part of a second with perfect regularity. Further, in each case, the time, reckoned from zero, required for the electromotive force or current to reach any given value, say the maximum value, or any portion of the curve below the maximum, is always the same. It follows therefore that, if, say in the case of an alternating-current motor whose period is 0·01 second of time, another electromotive force be generated, whose zero point is 0·0025 second behind the first, or which commences to generate after the first has been in operation for 0·0025 second of time, this electromotive force, and any current which it may set up, will always be behind the first electromotive force and current. Thus, when the first electromotive force and current are at their

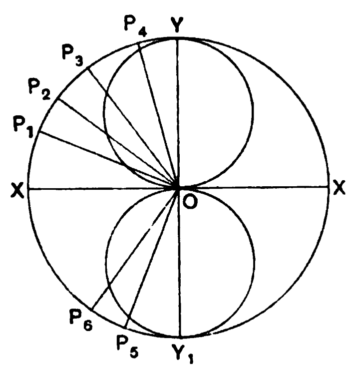

Fig. 7.—Diagram illustrating another Method of Ascertaining the Successive Values of the Sines of the Angles from 0 to 360 Degrees.

maximum positive values, the second electromotive force and current will be at zero. When the second electromotive force and current are at their maximum, the first electromotive force and current will be at their second zero value, and on the point of passing into the negative stage.

Electromotive forces and currents which are related to each other in this way are called diphase or two-phase, and their phases are stated to be 90 degrees apart, because, as already explained, when the revolving radius which is sweeping out the angle representing the first electromotive force has passed over 90 degrees, that which sweeps out the second electromotive force is at 0, just on the point of commencing its revolution. And machines furnishing currents related to each other in this way are called diphase or two-phase machines.

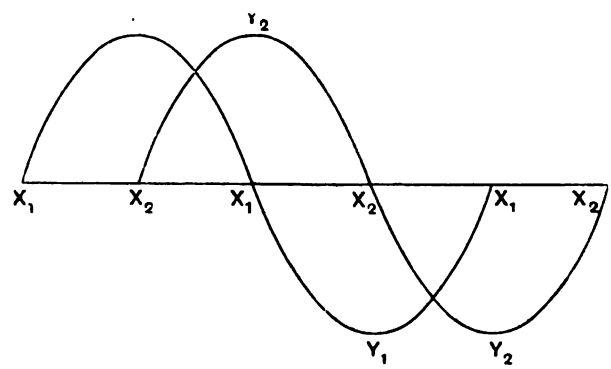


FIG. 8.—DIAGRAM ILLUSTRATING THE CHARACTERISTIC CURVES OF A DIPHASE ALTERNATOR: THE ELECTROMOTIVE FORCE OF THE SECOND PHASE BEING AT ZERO, WHEN THAT OF THE FIRST IS AT ITS MAXIMUM; AND THE ELECTROMOTIVE FORCE OF THE FIRST PHASE BEING AT ITS SECOND ZERO, WHEN THAT OF THE SECOND PHASE IS AT ITS MAXIMUM.

Diphase electromotive forces and currents are represented graphically by two curves, as shown in Fig. 8, in which it will be seen that the zero of the second curve $X_2Y_2$, is right under the maximum point of the first curve, and the second zero of the first curve is exactly under the maximum point of the second, the positions alternating right through the two cycles.

It is obvious, of course, that we are not confined to two currents. We may divide the 360 degrees into what portions we please; therefore in the latest development of alternators three electromotive forces and three currents are generated, these being spaced from each other, in time, by one third of the time required for a complete cycle. Thus, the second electromotive force and

current commence when the first have completed one third of their complete periods, or have risen to their maximum, and passed some way towards their second zero. The third electromotive force and current commence when the second have also completed one third of their full periods, and the first, two thirds. Thus taking 0·01 second of time again, as the period of one complete cycle, the second electromotive force and current will commence when the first have passed over 0·00$\dot{3}$ second of time, and the third electromotive force and current have passed over 0·00$\dot{6}$ second of time; or when the radii representing the first electromotive force and current, have respectively covered 120 degrees and 240 degrees out of the 360 degrees. This operation is expressed graphically by the

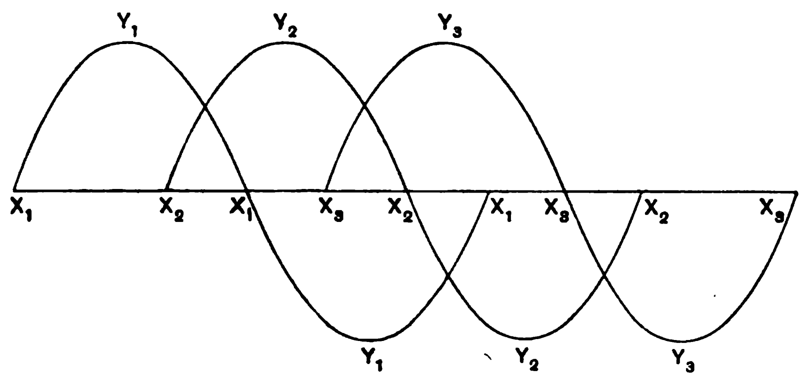


FIG. 9.—DIAGRAM ILLUSTRATING THE CHARACTERISTIC CURVES OF A TRIPHASE ALTERNATOR: THE SECOND CURRENT BEING ONE-THIRD OF A PERIOD AFTER THE FIRST CURRENT; THE THIRD CURRENT BEING ONE-THIRD OF A PERIOD AFTER THE SECOND CURRENT; AND SO ON.

three curves shown in Fig. 9, in which it will be seen that the second curve $X_2Y_2X_2$ commences to the right of the first and beyond the point of its maximum, in fact at the point at which the perpendicular dropped from the end of the radius after sweeping out 120 degrees from 0, would fall; the third $X_3Y_3X_3$ commencing where the perpendicular from 240 degrees would fall, but with the second 120 degrees carried on beyond the second zero of the first curve. Triphase, or, as they are usually termed, polyphase electromotive forces and currents, are stated to be 120 degrees apart, or to differ in phase by that quantity.

It is to be carefully noted that, though electromotive forces and currents are spoken of together, they do not always occur together, whether in single or monophase, diphase, or triphase apparatus.

The same forms of curves will represent equally, the one, two,

or three electromotive forces, or the one, two, or three currents, all rising and falling, that an alternator may be giving out; but distinct curves must be used to represent electromotive forces and currents for each phase, because, as will be seen, although apparently generated under the same conditions, and, at the same time, they are frequently not acting at the same time, the electromotive force often preceding in time the current whose office it is to create.

It will be understood also that the curves shown in Figs. 8 and and 9 represent electromotive forces or currents, generated by individual machines, but each electromotive force, and each current, as represented by its own curve, is quite separate from the other electromotive forces and currents, and separate paths are provided for them within and without the machine.

As will also be seen later, the use of diphase and triphase apparatus is to provide currents that will cause motors to operate somewhat on the lines of continuous-current motors, which the ordinary monophase or single-phase motor will not do.*

## IV.—Rectified Alternating Currents.

There is a modification of the alternating current, that is used for arc-lighting, from an alternating-current supply service, that had perhaps better be described, before passing on. It is known as the rectified current. It is not a continuous current, and it is not an alternating current, in the sense that it does not reverse; but it is continually altering in strength, rising and falling, both electromotive force and current, just as an alternating current does, but never being reversed. That is to say, with the rectified current, the electromotive force or the current, commences at zero, rises gradually to a maximum, then gradually falls to zero, then rises again, but in the same direction as before. It has the same cycle as the alternating current, except that two risings and fallings, both on the same side of the line, correspond to the one on one side and the second on the other side, of the ordinary alternating current. Its characteristic curve is shown in Fig. 10 in which XYX represents the curve, rising and falling, but never reversing. As before, separate curves are necessary to express the variations in electromotive force and in current, and a separate curve for each current-strength.

* Since this paper was written, in 1900, single-phase motors have been much improved, but they are not yet equal to diphase or triphase motors.

The rectified alternating current is, as its name implies, an alternating current, monophase; the simple alternating current. in which the currents have been turned all in one direction, by passing them through an apparatus, called "a rectifier," which will be explained later in the paper; the object being to use the currents for arc-lamps, the unidirectional current has the advantage, when used for arc-lighting, of directing the major portion of the luminous rays downward, while the arc fed by alternating currents directs half of them upwards, where in many cases they are practically wasted.

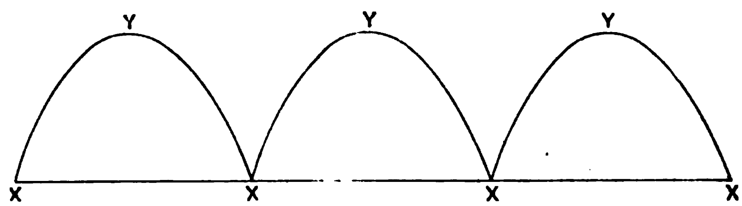


FIG. 10.—DIAGRAM ILLUSTRATING THE CHARACTERISTIC CURVES OF RECTIFIED ALTERNATING CURRENTS, UNIDIRECTIONAL CURRENTS OF VARIABLE STRENGTH, LIKE ALTERNATING CURRENTS, BUT WITHOUT REVERSAL.

## V.—WORKING VALUES OF ALTERNATING ELECTROMOTIVE FORCES AND CURRENTS.

One of the first questions that arises in connection with alternating-current supply is, what value of the electromotive force generated, or the current passing, must be taken for calculation?

With continuous currents, as members know from previous papers in the *Transactions*, and in those of the Institutes forming the Federation (previous to their union), two very simple laws enable the engineer to determine, under any conditions, what current, or what electromotive force he must provide to do certain work, and what resistance, what size of cables or other conductors, he must use under different conditions. These laws also enable him to calculate what current, or what power he is losing by leakage, or in other ways not tending to further the work which he has in hand. But with continuous-current apparatus, the engineer is always dealing with fixed quantities. The generator, for instance, furnishes a certain fixed electromotive force at its terminals, when run at a certain speed; and similarly he has a certain fixed electromotive force at the terminals of his lamps, or motors, when they are supplied with current by cables of a certain size and length, having certain currents passing through them.

But with alternating-current apparatus, all this is changed. As already explained, whether the generator be of the monophase, diphase, or triphase type, each electromotive force created is constantly rising and falling, and constantly being reversed; while the currents in the cables and apparatus are doing the same. What figures is he to take for his calculations, or must he use other calculations, other formulæ for the purpose?

The answer to the latter part of this question is, that in certain cases, those in which currents are delivered to circuits known as inductive circuits, his formulæ will have to be modified; this, and the cause will be explained later. But for simple, non-inductive circuits, such as those in which only incandescent lamps are served, the formulæ are the same, the only difficulty being in the quantities to be employed in solving the equations which he uses. Obviously, the quantities to be employed, both with electromotive force and current, must represent a mean, in some form or other. But it is not a simple mean, such as is obtained by halving the maximum. The actual figure in each case is represented by 0·707 of the maximum value.

As will be seen from the curves shown in Figs. 1, 8 and 9—and this is one of the great beauties of graphic representation, it enables one to see so much at a glance—the values of both electromotive force and current rise very rapidly at first, and more slowly as they approach the maximum, while they decrease slowly at first, after passing the maximum, and then more rapidly as they approach zero. The figures given above (0·707) are arrived at in the following manner. It will be remembered that with continuous currents there are two formulæ, by means of which the heat generated in any conductor, say an incandescent lamp or a cable, may be found, when either the current passing, or the electromotive force present at the ends of the conductor, and the resistance of the conductor, are known. They are:—

$$H = C^2Rt \text{ ; and } H = \frac{E^2}{R}t \text{ ;}$$

where H is the heat generated in the time t, C and E are the current and electromotive force respectively, and R the electrical resistance offered by the conductor to the passage of the current. Obviously for any given time, and for any given conductor, t and R are constant, so that we may say that H, the heat generated in a conductor varies as the square of the current passing, or as the

square of the electromotive force present at its terminals. Obviously, also, the alternating current which generates a certain quantity of heat in a given conductor, in a given time, does the same work as a given continuous current which generates the same quantity of heat in the same conductor in the same time. Obviously again, as the heating effect depends on the square of the electromotive force or of the current, the quantity that we are looking for must be also the square. As the electromotive force or current, delivered by an alternator rises and falls, each will generate heat in any conductor, in each instant, in proportion to the square of its value at that instant, so that the mean we have to find is the mean of the squares of all the values that the electromotive force and current assume throughout the cycle, and the value we are seeking, the working value of the electromotive force or current, the value which we are to use in our calculations will be the square root of this mean.

Hence follows the law which has been made so much fun of in after-dinner speeches, and which is at first such a stumbling block to the student, namely:—The working, or as it is termed, the effective or virtual electromotive force, and the effective or virtual current, are measured by the square root of the mean of the squares of all the electromotive forces or currents passed over during half the cycle; or

$$\text{Effective electromotive force} = \sqrt{\text{Mean of the squares of all the electromotive forces.}}$$
$$\text{Effective current} = \sqrt{\text{Mean of the squares of all the currents.}}$$

This value is also equal to the square root of the square of the maximum electromotive force or current divided by two, or to the maximum electromotive force or current divided by $\sqrt{2}$. **Thus:**

$$\text{Effective electromotive force} = \sqrt{\frac{E^2}{2}} = \frac{E}{\sqrt{2}} = 0{\cdot}707\ E.$$

$$\text{Effective current} = \sqrt{\frac{C^2}{2}} = \frac{C}{\sqrt{2}} = 0{\cdot}707\ C.$$

E and C standing in this case for the maximum values of the electromotive force and current, the values assumed in each case at the highest points of the curves. And conversely, the maximum electromotive force equals the effective electromotive force multiplied by 1·414; and the maximum current equals the effective current multiplied by 1·414.

With alternating-current apparatus, electromotive forces and currents are usually measured by some apparatus, such as the Cardew voltmeter, in which a wire is heated by the current passing, and in which the elongation of the wire, due to its expansion from the heat present, is measured. These instruments therefore measure the effective volts and ampères, which are 0·707 of the maximum. To find the maximum volts or ampères, therefore, the measured effective volts and ampères are multiplied by ($\sqrt{2}$ or) 1·414. Thus when we speak of an alternating current at 100 volts pressure or 2,000 volts pressure, we mean that the effective, or working volts are represented by those figures, and that apparatus, such as incandescent lamps, which have no inductive circuit, and which are made to furnish their normal light when supplied with a current at 100 volts pressure, will do so, no matter whether the pressure be continuous or alternating, providing that the 100 volts in the case of the alternating current be the effective pressure. This factor, of course, is a great convenience in the manufacture of incandescent lamps.

But the maximum pressure on the 100 volts alternating circuit is 141·4 volts, and on the 2,000 volts circuit, it is 2,828 volts. Similarly, when we are dealing, say, with 10 ampères of alternating current, we mean 10 effective ampères, the current rising to a maximum of 14·14 ampères.

This shows incidentally how it is that greater danger is incurred from the shock of an alternating current of a certain nominal voltage, a certain working voltage, than with the same voltage when the current is continuous; and why the insurance companies demand a higher insulation with the alternating currents of given value than with continuous currents, also why greater electrical strains are brought to bear upon certain parts of electrical apparatus with a given nominal alternating-electromotive force than with the same electromotive force if continuous current. With the continuous current, a 100 volts pressure gives a 100 volts strain, but with an alternating current, 100 volts pressure gives 282 volts strain or double the maximum pressure.

It should be mentioned here, incidentally, that some unidirectional pulsating currents, such as those furnished by some forms of high-tension (so-called continuous-current) dynamos, have these characteristics in a minor degree. It will be understood that, when we have an alternating electrical supply-service, at say 100

volts, this means that at every part of the service, wherever connection is made, the pressure is rising and falling, continually, from zero to + 141·4 volts, to zero and to − 141·4 volts; and that whatever be the current strength employed, this also is rising and falling and reversing in the same manner. When during the hours when only a few lamps are in use, and the current required is only say 10 ampères, the current supplied is still rising and falling and reversing, but it now never exceeds 14·14 ampères. When later on, as more light is required, and lamp after lamp is switched on, the current is still rising and falling, and reversing, and is still 200 times or 100 times, or 80 times in each second of time according to its periodicity: but as the current strength goes up, as lamps are turned on, the maximum rises, and with it the effective, or working current. As lamps are turned out, later on, the rising and falling, reversing and zero points still continue as when the full load was on, but the maximum now decreases, and with it the effective current, the square root of the mean of all the values assumed by the current in one half-cycle.

This applies also, as will be seen, to currents applied for power-distribution, whether monophase, diphase, or triphase. If a triphase motor, for instance, is taking 100 ampères effective current, each phase is furnishing a portion of this, and in each there are the same zero points, with the maxima, in their proper position, in time, relatively to each other, these maxima being 1·414 times the effective current in that phase delivery.

## VI.—Energy Expended in Alternating-current Circuits.

Although the engineer has thus obtained the values of electromotive force and current, that he is to use in any calculation, where each is used separately, he has not yet got the actual figures to be used in calculating what energy he is transforming in his circuit, nor what mechanical power he must provide. When we speak or write of a circuit between the ends of which an alternating electromotive force of say 100 volts exists, we mean that which has already been described as working or "effective" electromotive force, and when we say we have a certain number of alternating ampères passing in a circuit, we mean that number of working, or effective ampères, the number which is arrived at by the mean square-root method. But if, having a given "virtual" or effective electromotive force, and a given "virtual" or effective

current, in a circuit, we multiply these together and divide by 746, as we should do with continuous currents, and expect to find the energy transformed or expended in that circuit in horsepower, we shall, in many cases, find ourselves quite wrong.

It will be remembered that both electromotive force and current, rise gradually to a maximum and then fall gradually to zero, then rise to a maximum with the opposite sign, and so on: but in the majority of cases, owing to what is termed "induction," they do not rise and fall together. The electromotive force may in special cases have reached its maximum in one direction, before the current commences to pass in the circuit at all. In other cases, and these are more general, the current "lags," as it is termed, behind the electromotive force, by a definite angle. That is to say, if in Fig. 5 the radius, representing the angle swept over by the electromotive force during a cycle, has passed over 45 degrees before the radius representing the current commences to move, the current is said to "lag" by 45 degrees, or 45 degrees is said to be the angle of "lag," usually denoted by $\phi$.

Now in order to find the energy expended at any instant, we multiply the electromotive force present at that instant, by the current passing at the same instant, and to find the effective energy employed, we must take a number of these values, and take the mean. But it will be obvious that, when the current lags behind the electromotive force, the energy, being expended at any instant, is not the same as with the continuous current under similar circumstances. Thus with continuous currents, if a given electromotive force and resistance are present, the current is known at once and the product of the two gives the energy being expended. With the alternating current, in nearly every case it is the product of the electromotive force and a smaller current during two quarters of each cycle, and of an electromotive force and a larger current during the other two quarters.

Thus, in the case where the current "lags" 45 degrees behind the electromotive force, the energy being expended, say when the electromotive force is at its maximum, will be measured by the product of the maximum electromotive force, and the current at 45 degrees, while, when the current has reached its maximum, the electromotive force will have descended 45 degrees, or be at 135 degrees. It will be noted that when the current lags by 90 degrees, no energy is actually being expended when the electro-

motive force is at its maximum, since any quantity multiplied by 0 = 0. This is the paradoxical case of generating a current, yet not generating one.

The rule for finding the rate of energy that is being expended with alternating currents is, $W = EC \cos \phi$. If E be in volts, and C in ampères, dividing the result by 746 gives the horsepower, where W is the energy expended, or work done, E the impressed electromotive force, C the effective current, and $\phi$ the angle by which the current lags behind the electromotive force. The impressed electromotive force, a term which will be explained fully later on, is the actual electromotive force delivered to the circuit when induction is present, which is usually larger than would otherwise be necessary owing to induction, to the opposition created by induction.

It will be understood that when we speak of a certain impressed electromotive force being delivered to a circuit, we mean an electromotive force whose value corresponds to that which a continuous-current electromotive force would have, if required to perform the work before the alternating-electromotive force, and which also has the same relation to its maximum, as the effective electromotive foıce already described.

## VII.—INDUCTION.

And now as to how this arises. It is due to electromagnetic induction.

Induction is perhaps one of the most difficult things to understand, in connection with electricity. Induction is of two kinds, electrostatic and electrodynamic, or, as it is usually termed, electromagnetic. Wherever an electrical pressure is present, that is to say an electromotive force between two points, or two conducting surfaces, electrostatic induction is also present, producing what is termed an electrostatic charge, while the two surfaces between which the pressure exists, with the insulating material between, are termed a condenser, and the action of the charge is to hold, within the condenser, a certain amount of the molecular and ethereal motions we call electricity, just as a certain quantity of the motion we know as heat is held in a heated body.

Thus, one first result of the passage of an electric current through a conductor is the charging of the electrical condenser of

which the conductor forms one surface; and when the pressure on the conductor is withdrawn, this charge pours out again into the conductor in both directions. A familiar instance of this is the case of the submarine cable, in which signals are formed at the distant end, by the action of successive currents, usually in opposite directions, upon some form of magnetic needle. Each motion of the needle, after the first, is delayed and rendered very much less, by the fact that the reversed current, which follows, has to neutralize the current which pours out from the cable itself, in the same direction as the previous current, owing to the release of the electrostatic charge. Also, the troubles of the telephone engineer, engaged in protecting individual wires from the invasion of currents that interfere with his ordinary working currents, are increased by the fact that he is constantly creating electrostatic charges, which are as constantly discharging through his telephone-wires. As will be seen later on, with alternating currents, used for electric lighting or transmission of power, a similar trouble is met with.

Electromagnetic induction arises in the neighbourhood of any conductor, whenever any change takes place in the current passing in the conductor; that is to say, when the current first passes, when it ceases, and when its strength is increased or decreased. It will be remembered that in the neighbourhood of either a permanent or an electromagnet, iron filings, if allowed to do so, will arrange themselves in definite curves, which Faraday called lines of force, and that these lines, as represented by the iron filings, are densest where the magnetic field is strongest. Round every conductor, such lines are created when a current is passing, and they take the form of concentric circles, the conductor being the common centre, and the strength of the field, as exhibited by the iron filings, if placed round the conductor, being greatest in its immediate neighbourhood, and weakening as the distance from the conductor increases.

The density of the lines, and the strength of the magnetic field which they represent, increase in exact proportion to any increase in the current-strength, and *vice versa*. Any change in the density of the lines of force surrounding a conductor, in which an electric current is passing, creates electromotive forces in every conductor in the neighbourhood, every conductor which cuts the lines. Obviously such changes may be due to increase or decrease

of the strength of the current, or to motion on the part of one or both conductors, that in which the current is passing and that in which an electromotive force is created, by induction, as it is termed.

In the dynamo, the electromotive forces created in the armature conductors are due to changes in the density of the lines of force passing through each individual conductor, produced by the motion of the conductor itself through the magnetic field of the dynamo. In the case of telegraph and telephone wires running parallel to each other, electromotive forces are created in one wire by the passage of currents in another wire, and by the increase or decrease of those currents.

But it is not necessary that the conductor in which induction takes place shall be apart from, or separated from the conductor in which the inducing current is passing. The passage of a current in a conductor, by creating lines of force around itself, also by that operation generates an electromotive force in itself, in opposition to the first electromotive force, and it is this which delays the attainment of its full strength by the current in any conductor, under the conditions ruling.

When, also, in a great many forms of electrical apparatus, as in dynamo-generators, motors and transformers, the conductor is coiled on itself, each turn of the conductor behaves just as a separate conductor would; the passage of the current through each turn of the coil creates lines of force surrounding that portion of the conductor which forms that turn of the coil, thereby creating an opposing electromotive force in itself, and in every turn of the coil.

The cessation of the current also creates an electromotive force in the same direction as that which caused the current itself to pass in the conductor, owing to the change thereby produced in the lines of force surrounding the conductor, and this electromotive force is created as when the current first passes, in every turn of the coil, each turn adding to the total electromotive force generated.

It is this induced electromotive force, created on breaking the circuit of a dynamo, particularly on breaking the circuit where the same current passes through a number of turns of wire, that causes such disastrous shocks, with comparatively low voltage-apparatus, and that leads to sparking through comparatively thick

insulation, and other troubles. The electromotive force is only present for a very short time, but while it is present, its value is very high.

But, as already pointed out, it is not necessary for the current to be made, or broken in any conductor, for induction to take place in that, and in neighbouring conductors. Increase or decrease of current-strength, by increasing and decreasing the density of the lines of force surrounding it, creates electromotive forces within itself, and within neighbouring conductors, the direction of these electromotive forces being:—(1) Such as to oppose that creating the primary current, when the latter is increasing; and (2) such as will add to that creating the primary current when the latter is decreasing.

It will be understood, therefore, that whenever a current of electricity passes through a conductor, before it can arrive at its full strength according to the conditions present, it has to charge the condenser, of which the conductor forms a part, and it also has to create the magnetic field surrounding it. Further, this charging of the condenser and creation of the magnetic field constitute an actual storage of potential energy, just as lifting a weight against the force of gravity does, and, just as the weight, on being allowed to fall, will give up the energy that was expended in raising it; so the electric condenser, and the electromagnetic field will each give back the energy stored in them, when the pressure which created them is removed. So too, where we have a weight alternately rising and falling, as, say, on a switchback railway, we have alternately expenditure of energy and return of energy expended, so we have with alternating currents of electricity, alternately expenditure and storage of energy in the forms named, and return of a portion of that energy. Electricians term these processes electrostatic and electromagnetic induction.

And now, as to their effect upon the electric currents generated: Let us take electromagnetic induction first, as it is the most important, and the most troublesome.

As already explained, when an electromotive force is applied to a conductor, and an electric current commences to pass through the conductor, immediately a magnetic field is created around the conductor, which generates in the conductor an electromotive force opposing its passage; and when, as with an alternating current, the latter is continually changing in value, the electromotive force opposing it is also continually changing in value.

The value of the induced or opposing electromotive force is greatest when the current-strength is least, and least when the current-strength is greatest: but during the whole period of the passage of an alternating-current through any conductor, the electromotive force has not only to overcome the resistance of the conductor, but also this opposing induced electromotive force; and so it follows that when a given effective electromotive force (square root of the mean square value) generated by the alternator, is opposed to a given resistance, the current actually passing in the conductors, including those forming the generator itself, is less than it would be with the equivalent continuous electromotive force, or, on the other hand, in order that an alternating current of given strength shall pass through any system of conductors, the electromotive force delivered by the generator, the impressed electromotive force as it is termed, must be greater than would be necessary with continuous electromotive force, and the cause is the induced opposing electromotive force referred to above.

But the opposition offered by the induced electromotive force does not take the form simply of resistance. We cannot say that we have a certain impressed electromotive force and a certain induced electromotive force, and therefore a certain resultant pressure, which is merely the difference between the two.

The action of the induced electromotive force is to delay the passage of the current, to delay its starting, so that the current is actually weaker than it would have been, but for the induced electromotive force; or at a later period of the cycle the electromotive force may be less than would rule with the given current, and therefore the product of the two, electromotive force and current, is less, owing to the fact that, by reason of the creation of this induced electromotive force, the current curve starts later than the electromotive-force curve.

And now, as to the ratio between the current and the induced electromotive force, what law governs them? and how is the resultant current affected? The electromotive force induced in any conductor, by alterations in the density of the lines of force passing, or threaded through the conductor, depends upon the rate of change in the density of the lines; and thus, where the induction is due to an electric current, depends on the rate at which the current changes its value. The induced electromotive force is greatest when the strength of the current is changing most rapidly, and least when it is changing at its slowest rate.

Now, with alternating-currents, both electromotive force and current vary, as has been mentioned, in nearly all cases, as the value of the sine of the angle made by the revolving radius in Fig. 5 varies; and the variation is greatest when the angle is 0 degrees and 180 degrees, or 360 degrees, and least when the angle is 90 degrees or 270 degrees. That is to say, the rate of change of the current-strength, the rate of change in the density of the lines of force surrounding the conductor, and, therefore, the induced electromotive force, are all greatest when the current-strength is least, when the current-strength is passing through its zero values; and least when the current-strength is passing through its maximum values. Or the phenomena may be interpreted thus:— When the primary electromotive force generated by the alternator commences to increase in value, from the zero position, it would also cause an electric current to pass through the circuit to which it is connected, but for the fact that the current so generated, or the lines of force resulting from it, immediately induce a counter electromotive force which delays the passage of the current until the rate of change is smaller: and so the current does not pass until the electromotive force has passed through a certain angle.

The value of this induced electromotive force is dependent on the rate of change in the current inducing it, that is on the rate of change in the value of the sine of the angle made by the revolving radius, and the rate of change in value of the sine of any angle is measured by the cosine of the same angle. That is to say, where the changes in the strength of an alternating current may be represented by the changes in the value of the sine of the angle made by a revolving radius from 0 to 360 degrees, the time occupied in passing over the circle being that occupied by one complete cycle, the electromotive force induced in itself by that current may be represented by the cosine of the same angle.

The cosine of any angle is the ratio between the base, the side of the right angle adjoining the angle, and the side opposite the right angle, the hypothenuse; thus, in Fig. 5:—

$$\text{Sin}\ \theta = \frac{\text{Perpendicular}}{\text{Hypothenuse}} = \frac{\text{PN}}{\text{OP}}.$$

$$\text{Cos}\ \theta = \frac{\text{Base}}{\text{Hypothenuse}} = \frac{\text{ON}}{\text{OP}}.^{*}$$

* $\theta$ is the angle swept out by the radius; and $\phi$, the angle included between the radii, representing electromotive force and current, or the angle of lag.

The hypothenuse being the radius, and therefore constant, it has been shown that the sine varies as the perpendicular; and similarly, the cosine will vary as the base. Thus, when the angle is 0, the base is equal to the radius and therefore the cosine of 0 degrees is equal to 1. When the angle is 90 degrees, there is no base-line and the cosine of 90 degrees is therefore equal to 0. Thus, when the electromotive force and current start on their journey through their cycle of values, at 0 degrees the induced electromotive force is equal to the primary electromotive force, and so no current passes. At 90 degrees, or when the current is at its maximum, the induced electromotive force is 0.

It will be seen from this statement that the greater the induced electromotive force, the more will the current be detained, or the more it will lag, after the electromotive force which creates it.

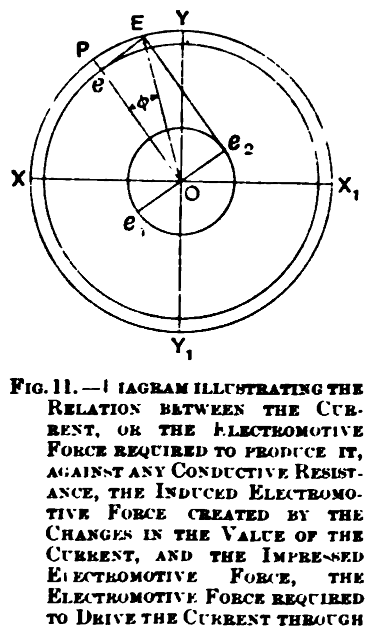


FIG. 11.—DIAGRAM ILLUSTRATING THE RELATION BETWEEN THE CURRENT, OR THE ELECTROMOTIVE FORCE REQUIRED TO PRODUCE IT, AGAINST ANY CONDUCTIVE RESISTANCE, THE INDUCED ELECTROMOTIVE FORCE CREATED BY THE CHANGES IN THE VALUE OF THE CURRENT, AND THE IMPRESSED ELECTROMOTIVE FORCE, THE ELECTROMOTIVE FORCE REQUIRED TO DRIVE THE CURRENT THROUGH THE CONDUCTIVE RESISTANCE, NOTWITHSTANDING THE OPPOSITION OF THE INDUCED ELECTROMOTIVE FORCE, AND THE ANGLE, $\phi$, OF LAG.

Meanwhile, we have to note that the cosine of any angle is equal to the sine of the complement of that angle, or if $\theta$ be the angle, to sine $(90 - \theta)$, and it is also equal to sine $(90 + \theta)$ or to $(360 - \theta)$. That is to say, if the primary electromotive force and current vary as the sine of the angle made by the revolving radius, the induced electromotive force created by the current will vary as the sine of the angle made by the radius which denotes the current, moved forward or back a quarter of the circle, and with the sign of opposition.

In Fig. 11, which is also a clock-diagram, are represented the three quantities: the alternating current passing in the circuit: the electromotive force induced in the circuit by the variations of this current: and the impressed electromotive force, the total electromotive force required to be, and furnished by the dynamo, in order to drive the current through the circuit, in opposition to the ordinary resistance of the circuit, and to the induced electro-

motive force created by the variations in the current-strength. The values of the different quantities are represented, diagrammatically, by the lengths of the radii of their own circles. That of the impressed electromotive force is the longest, as denoting the highest value, and that of the induced electromotive force is the shortest, it being usually small in proportion to the other quantities. The radius representing the induced electromotive force is also placed in its proper position, at right angles to, and opposing that representing the current. The radius representing the impressed electromotive force, as will be seen, forms the diagonal of a rectangle, of which the radius representing current forms one side, and a radius equal and opposite to that representing the induced electromotive force forms the other side.

In Fig. 11, $XX_1$ is the line of origin as before; OP is the radius which is sweeping out the successive angles; Oe is the radius representing the current; $Oe_1$ that representing the induced electromotive force; $Oe_2$ its equivalent moved on through 90 degrees; and OE the impressed electromotive force. It will be noted that Oe, the radius representing the current, may be taken as that quantity, or the electromotive force required to produce it, where only the ordinary conductive resistance is present.

The triangles, EOe and $EOe_2$, which are similar, also show graphically the relation between the electromotive force that the dynamo has to furnish, the conductive resistance that it has to overcome, and the inductive opposing electromotive force. It also shows the position of the current represented by the radius, Oe, lagging, in time, behind the electromotive force which creates it. The angle eOE is the angle of "lag," usually denoted by $\phi$. The triangle eOE is often used, apart from its surroundings, to denote these relations. Thus, in Fig. 12, eE, the induced electromotive force is termed the inductance, Oe as before, the resistance, and OE, their resultant, or the electromotive force required to overcome it, the impedance. It will be noted also that:—

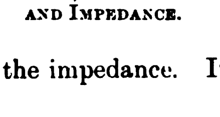


FIG. 12.—DIAGRAM ILLUSTRATING THE RELATION BETWEEN CONDUCTIVE RESISTANCE, INDUCTANCE AND IMPEDANCE.

$$\frac{Ee}{Oe} = \tan \phi,$$

the angle of lag, which is rather a useful equation at times, as the angle of lag is sometimes awkward to calculate, and until it is known, the actual quantity of energy required, or being converted, cannot be found. It may further be noted that: $OE^2 = Oe^2 + eE^2$; or $OE = \sqrt{Oe^2 + eE^2}$; which means that the impedance, the quantity which corresponds to resistance with continuous currents is equal to the square root of the sum of the squares of the resistance and the inductance.

Further, although we cannot say that we have the difference of two electromotive forces, the impressed, and that induced, to use in our calculations, we can calculate the quantities whose squares we require, provided certain other quantities are known; and hence we can calculate the numerical value of the impedance, and we can then obtain the value of the effective current passing in the circuit, with a given electromotive force at the terminals of the dynamo. The value of the resistance, Oe, is found from the dimensions and material of the conductors present in the circuit, the cables, dynamo-coils, etc., as with the continuous current. The value of the inductance is measured by the product of the self-induction of the circuit (a quantity found by observation, or by calculation) multiplied by the frequency of the alternations.

Perhaps a little further explanation is needed here. It will be remembered that, with continuous currents, the electromotive force required to drive a certain current through a certain conductor or system of conductors, is measured by the product of the required current by the resistance of the conductor, or system of conductors through which it is to be driven; or:—$E = CR$. Where E represents the electromotive force, R the resistance, and C the current, this being one of the forms taken by Ohm's law.

With alternating currents, however, wherever any part of the circuit is subject to induction (and the generator itself always is, as are also the transformers, the motors, and other apparatus) the electromotive force generated by the dynamo, or delivered to the circuit, has to overcome the electromotive force of induction, as well as the resistance offered by the conductors; or rather that portion of the induced electromotive force which is acting directly against the electromotive force that is tending to drive the current through the conductors. Really to perform the work, we have to overcome two forces, one a resistance, and the other an active

electromotive force, the action of the two not being simultaneous, but in such a manner that they can be represented by the two sides of a right-angled triangle.

Now, just as in mechanics we represent any two or more forces acting on a given body by straight lines, inclined to each other in the directions in which the forces are tending to move the body, and of lengths proportional to the magnitude of the forces: so we can also represent the electromotive forces required, both in magnitude and direction. Also, just as in mechanics, we represent the resultant force, the direction in which the body will move under the influence of the two forces, by the diagonal of the parallelogram drawn upon the two lines representing the two forces, and the magnitude of the force acting on the body to impel it in the direction of the resultant force, by the length of the diagonal of that parallelogram, so we can represent the resultant electromotive force required to overcome the combined action of the resistance and induced electromotive force, both in magnitude and time, by the diagonal of the parallelogram, or rectangle whose sides represent the resistances which it is required to overcome.

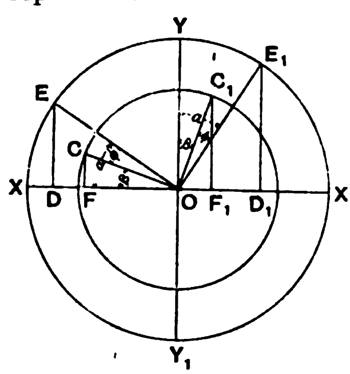


FIG. 13.—DIAGRAM SHOWING HOW THE FORMULA, $W = EC \cos \phi$, IS OBTAINED.

We are now in a position to understand the reason for multiplying the product of electromotive force and current by the cosine of the angle of lag, "the power-factor," as it is termed. But in order to make it clear, we must make another small excursion into trigonometry. In Fig. 13, which is a double-clock diagram, we have two sets of radii, representing electromotive force and current at certain positions in their cycles, and again when each has passed through a quarter of a complete cycle. OE and OC represent electromotive force and current respectively at a point, in time, before the electromotive force attains its maximum: the current, as shown being at a point, in time, behind the electromotive force. $OE_1$ and $OC_1$ represent the electromotive force and current when they have passed through 90 degrees from the positions OE and OC. ED and CF represent the values of the

sines of the angles DOE, and FOC, passed over respectively by the radii representing electromotive force and current. $E_1D_1$ and $C_1F_1$ represent the values of the sines of the angles passed over by the same radii, 90 degrees, later on.

Now, in order to obtain the correct value of the product of the electromotive force by the current throughout the cycle, we require to take all the values at each instant and find their mean, but we can do the same at once, by taking the mean of two values 90 degrees apart, since we may take as many pairs 90 degrees apart as we please. And we obtain the mean by adding the two values together and dividing by two. Thus, W, the power being given to the circuit, will be represented at any moment by half the sum of the powers at two moments, a quarter of a cycle apart or:—

$$W = \frac{ED \times CF + E_1D_1 \times C_1F_1}{2}.$$

But $ED = OE \sin DOE$, and $CF = OC \sin FOC$. Let $\alpha$ be the angle DOE, and $\beta$ the angle FOC. Then the angle EOC is equal to $(\alpha - \beta)$, and is the angle of lag, $\phi$. Then, $ED = OE \sin \alpha$, and $CF = OC \sin \beta$ Similarly $E_1D_1 = OE_1 \cos D_1E_1O = OE_1 \cos \alpha$; and $C_1F_1 = OC_1 \cos F_1C_1O = OC_1 \cos \beta$. Since by similar triangles, the angles DOE and $D_1E_1O$ are equal; and also the angles FOC and $F_1C_1O$. Therefore:—

$$W = \frac{OE \sin \alpha \times OC \sin \beta + OE_1 \cos \alpha \times OC_1 \cos \beta}{2}.$$

But, OE and $OE_1$ are equal, and also OC and $OC_1$; therefore:—

$$W = \frac{OE \times OC (\sin \alpha \sin \beta + \cos \alpha \cos \beta)}{2}.$$

And further:—

$$W = \frac{OE \times OC \cos (\alpha - \beta)}{2}.$$

But $\alpha - \beta$ is the angle of lag, $\phi$, the angle by which the current radius lags behind that representing the electromotive force, therefore:—

$$W = \frac{OE \times OC \cos \phi}{2}.$$

But OE and OC are the radii representing the maximum values of electromotive force and current and as we have seen above:—The effective electromotive force equals the maximum electromotive force divided by the square root of 2; and the effective current equals the maximum current divided by the square

root of 2. And the maximum electromotive force equals the effective electromotive force multiplied by the square root of 2; and the maximum current equals the effective current multiplied by the square root of 2. Therefore, the energy expended: —

$$W = \frac{\text{Effective electromotive force} \times \sqrt{2} \times \text{effective current} \times \sqrt{2} \times \cos\phi}{2},$$

$$= \text{Effective electromotive force} \times \text{effective current} \times \cos\phi,$$

$\phi$ being the angle, by which the current is behind the electromotive force, in time, 360 degrees being a complete cycle. That is to say, to calculate the energy required in horsepower for a given alternator, or that is being expended in any circuit or portion of circuit, in which an alternating current is passing, we obtain the values of the effective impressed electromotive force, the effective current passing in the circuit, the angle or the portion of a cycle by which the current is behind the impressed electromotive force, and we multiply these effective values together, and the product by the cosine of the angle referred to, and divide by 746, the number of Watts in one horsepower; or: —

$$W \text{ in horsepower} = \frac{\text{Effective E} \times \text{effective C} \times \cos\phi}{746}.$$

And this equation is true, whether there be one set of currents delivered by an alternator, or two, or three; bearing in mind, however, that each current and each electromotive force, and the angles of lag in each, have to enter into the calculation in each case. The quantity cos $\phi$, or the cosine of the angle of lag, is termed the power-factor, the quantity that the engineer requires to know, as will be seen later on, in calculating cables and other quantities in connection with power-distribution by alternating currents.

Central-station engineers will sometimes boast that they have a high power-factor. They mean that their apparatus is so designed that electromagnetic induction is low, and so the current does not lag much, and cos $\phi$ approaches unity.

It should be noted, *en passant*, that the cosine of this angle, the cosine $\phi$ referred to just above, must not be confounded with the cosine of the angle through which the current-radius has passed; $\phi$ is the angle of lag, the angular difference between the two radii, the angular difference between the two angles representing electromotive force and current, representing also the

difference in time between impressed electromotive force and current. The induced electromotive force varies as the cosine of the angle representing the current, the angle representing the portion of the cycle that the current has passed through.

The current passing in the circuit varies as the sine of the angle swept over by the radius representing current, during its cycle, the electromotive force induced by the current, owing to the variation in the strength of the magnetic field surrounding the conductors carrying the current, varies in proportion to the rate of change of the field, or of the current-strength, and therefore to the rate of change in the value of the sine of the angle that denotes the varying values of the current, a rate of change which is measured by the cosine of the same angle.

## VIII.—Electrostatic Induction.

The effect of electrostatic induction upon the working of a circuit in which alternating currents are passing, is exactly the reverse of that of electromagnetic induction. Where the latter, as we have seen, causes the current to lag behind the electromotive force creating it, the former actually causes the current to be in advance of the electromotive force. Or, to put the matter more accurately, where the induced electromotive force created by the electromagnetic induction, acts at right angles to, but behind the generating electromotive force and therefore requires an opposing electromotive force also at right angles, but in advance, to balance it, the electromotive force due to electrostatic induction, to the energy of the charge stored in the insulating envelope of the cable, etc., acts also at right angles to the generating electromotive force, or to the current, but in advance, and therefore requires an electromotive force to oppose it, at right angles to, but behind the current. These expressions refer, it will be understood, to the position assigned to the radial lines representing the different electromotive forces and currents at any given instant. It follows, of course, that an induced electromagnetic electromotive force, may be balanced by an induced electrostatic electromotive force, the result being that the current and electromotive force come into phase and the power-factor, as it is termed, cos $\phi$, disappears.

Many suggestions have been made by electrical engineers to make use of this property of electrostatic induction, to overcome the troubles of electromagnetic induction, by the addition of arti-

ficial condensers, working in connection with alternating electric-light circuits, but so far, they have not met with much success.

The artificial condenser is an expensive, and a troublesome piece of apparatus to make. It has also a nasty knack of breaking down under continued strain, by sparking across between its conductors; and it is hardly suitable for mining work.

As already explained, the electric-light or power cable, consisting of a conductor enveloped in some form of insulator, or dielectric, as it is termed, such as indiarubber, jute, etc., this insulating envelope being itself often enclosed in a second conductor, such as a leaden tube, or an armour of iron wires, and having, in any case, its outer surface in direct connection with "earth," forms a condenser, which receives a charge, and redelivers it to the inner conductor during every cycle of alternations.

Where concentric cables are used (that is to say, cables in which the two conductors are formed into one cable), and where, as is usually the case, the outer conductor is also insulated, and further protected by a leaden, or iron tube, or armour outside all, the protecting tube, or armour being in contact with the ground everywhere, there are two condensers; one between the two conductors of the cable, and the other between the outer conductor and earth; and both take part in the electrostatic inductive action.

Where the cables are long, and the frequency of the current, the number of alternations per second, is high, the capacity of the cables and their measured electrostatic induction, may neutralize, and even overbalance the electromagnetic induction, so that the current arriving at the consumer's end, is in advance of the electromotive force creating it, in place of behind it. This is actually the case in some portions of the Niagara Falls transmission-scheme.

It must not be imagined that anything is gained by the current being in advance of the electromotive force, except in so far as it neutralizes the lag due to electromagnetic induction. Both lag and lead mean that a certain portion of the current is not available for useful work, and so a larger current has to be generated than would otherwise be necessary.

The electromotive force due to electrostatic induction in the condenser formed by the cable follows nearly the same law as that of electromagnetic induction, that is:—It varies in proportion to

the rate at which the value of the sine of the angle representing the changing value of the electromotive force varies, and the measure of the rate of change of the value of the sine of any angle, as before mentioned, is the cosine of the same angle. Hence, the electromotive force due to the electrostatic induction created by the condenser-action of the cable, which has to be overcome, by the impressed electromotive force which adds to the electromotive force that the dynamo must be capable of furnishing, is proportional to the cosine of the angle representing the changing values of the electromotive force, through its cycle.

The electromotive force induced electrostatically, is usually represented graphically, with reference to the other quantities, in the same manner, as electromagnetic induction, with the distinction mentioned, that the lines representing the two quantities are 180 degrees apart.

Thus in Fig. 11, while $Oe_1$ represents the electromotive force created by electromagnetic induction, the electromotive force created by electrostatic induction would be represented by a distance measured along the line $Oe_2$, and the electromotive force required to balance the resultant inductance would be set off along the common line $e_1e_2$, in a direction opposite to, left or right of, zero, according as electrostatic or electromagnetic induction was the most powerful: the length set off being the difference of the two quantities.

The electromotive force due to electrostatic induction, when any is present, also takes its place in the perpendicular of the triangle in Fig. 12, the length of eE being the difference between the two induced electromotive forces.

The value of the impedance also is found as before, from the formula:—$OE = \sqrt{Oe^2 + eE^2}$, bearing in mind that where only electrostatic induction is present, eE represents that quantity, where only electromagnetic induction is present eE represents that quantity and that where both are present, eE represents their difference; the formula then becoming:—The impedance equals the square root of the sum of the square of the resistance, plus the square of the frequency of alternations by the co-efficient of induction, minus the reciprocal of the product of the condenser-capacity of the cable by the frequency; this last being the measurement of the electromotive force due to the electrostatic induction.

These quantities can be calculated, and the impedance and

electromotive force required at the terminals of the generator determined.

It has been stated, in an earlier part of the paper, that the phenomena of induction were really storage of energy, in the magnetic field and in the cable-condenser, and that the energy, so stored, was given back again, just as the energy expended in raising a weight from the ground is given back when the body falls to the ground. This is strictly correct; but, as in all other cases, the whole of the stored energy is not given back usefully to the circuit, from which it was taken. There is the usual charge for storage; a portion of the stored energy being converted into heat, and being dissipated as heat. So that, as far as the useful work to be performed by the apparatus is concerned, the induction phenomena, though not all loss, yet involve a certain loss, depending upon the conditions ruling; and one of the objects of a careful study of the subject is to enable the engineer to reduce these losses, as in other cases, to their lowest figure.

### IX.--The Phenomena of Resonance.

Another matter should now be dealt with before leaving the theoretical part of the subject, namely, the phenomena which created such surprise when first announced as being present on the mains of the London Electric Supply Corporation, that are used to transport electric energy from Deptford to the west end of London. The phenomena have received the name of electrical resonance, and they form a part of the phenomena due to the charging and discharging of the condenser formed by the supply-cables. The effects are an increase of pressure at the Westminster end of the cables, above that of the apparatus supplying them at Deptford. The cables, which will be described more fully, in the second part of the paper, consist of two copper tubes, placed one inside the other, with an insulating material between them. The tubes form the going and returning cables for the electric supply, and they are subject to a pressure of 10,000 volts, at the Deptford end, where the generating-station is located.

At the sub-station at Trafalgar Square, where the electrical energy is transformed down from the pressure of 10,000 volts to 1,000 volts, at which pressure it is further transported to other transformers, the pressure was found to be in some cases as

much as 10 per cent. above that supposed to exist at Deptford. The fact really is, however, that the increase of pressure takes place all over the cable; and that the pressure is really higher at Deptford, after the current has entered the cable, than at Trafalgar Square, before it leaves the cable. The effect lessens as the cables are loaded up, and it does not affect the current delivered to consumers, as the increase is dealt with in the sub-station.

The cause of the phenomena may be explained as follows:— Although the charging of an electrical condenser, such as an insulated cable, consists in current, or rather, the wave-motion we know as electricity, pouring into the insulating envelope, the operation is not a continuous one, but consists of a number of oscillatory movements of the charge, something after the manner of the wave created when a stone is thrown into water; although the wave is ever widening its circle, smaller waves move to and fro from and to the centre for some time after the original disturbance. This is the case when a simple charge or discharge takes place, each consisting of a series of oscillations, finally dying down, and neither the charge nor discharge is complete till the oscillations have finished.

When the charge is created by an alternating electromotive force, itself not only oscillating, but rising and falling in value, we have one series of oscillations, those of the alternating electromotive force, superposed upon another set of oscillations, those due to the operation of charging the condenser. The combination of the two motions will produce results varying with the conditions present.

Perhaps the matter will be better understood, if we suppose a pendulum to be in motion, from an impulse imparted to it, in the usual way; and while still oscillating, another impulse to be brought to bear upon it, at some point, or points of its path. The effect of the second impulse upon the motion of the pendulum, will vary with the conditions. It may quickly extinguish the motion created by the first impulse, it may lessen it gradually; but, it may also, if it coincide in direction and time with the motion created by the first motion, increase the amplitude of that motion.

And this is what takes place, when the phenomena of electrical resonance occur. The continuing impulse of the alternating electromotive force agrees in time and direction with the motion due to the operation of charging the condenser, with the result that the maximum swing the maximum electromotive force at

the condenser-plates, the copper tubes, or other conductors, is increased, and with it the effective electromotive force.

It will be understood that there is no creation of energy out of nothing in this matter. The energy delivered, the whole of it, as well as that consumed uselessly so far as the lighting is concerned, has to be furnished by the engines at the generating-station; and the phenomena really increase the consumption of coal, to perform certain work; everything too, remaining the same, in every other respect. Every apparatus takes its toll for transporting, or for converting the energy. The one thing altered is that the energy is delivered at a higher pressure than the engineer intended; while the increase of pressure varies with the varying conditions of the load; and the engineer has to provide apparatus to reduce this additional pressure to the figure required by him, and to deal with the variations as they arise.*

## X.—Construction of Alternating-current Generators.

The principles of the construction of dynamos that are to furnish alternating currents, are exactly the same as those on which the continuous-current dynamo is made; with the essential difference that, while in the continuous-current dynamo special arrangements are made to turn all the currents generated in one direction, to have a single procession of waves, in the generator for alternating-currents special arrangements are made to secure a given number of alternations in a given time.

There is also the important difference between alternating-current generator dynamos, whether simple, single-phase, diphase or triphase, however arranged, and continuous-current dynamo generators, that, while the field-magnet coils of continuous-current generators can be, and nearly always are, furnished with current generated by their own armatures; with alternating-current generators, the current for the coils of the field-magnets is provided by a separate machine furnishing continuous current, the reason being that the alternating current would not furnish the magnetic fields required.

The exciter-dynamo, as it is called, is often carried on the same framework as the alternator: its armature either being connected mechanically to the revolving part of the alternator, or some other convenient arrangement being made, such as ropes,

* Advantage is being taken of these phenomena to generate alternating currents of enormous pressure and of very high frequency, for use in medical work.

or belts, for driving it from the shaft of the alternator, or from a second pulley on the driving-engine.

In generating-stations, where several alternators are in use, it is sometimes the practice to excite the field-magnets of all the machines from one continuous-current dynamo machine, driven by its own engine. One of these arrangements rules with all forms of alternator-dynamo generators. In addition to this, as will be easily understood, the alternator-generator requires no commutator, since the currents are not intended to be arranged all in one direction.

The armature-coils, in the simple, or single-phase alternator, form one continuous length of wire, or strip, with the ends, connected to two rings carried by the armature-shaft, where the armature revolves, and to two terminals where the armature is stationary; and it is to these collecting-rings, or these terminals, that the current for the external circuit is delivered. When the armature revolves, brushes, or strips of brass or copper, rest on the collecting-rings, and take the current from them; but the rings and brushes are not the same as the commutator and brushes of the continuous-current machine, and they only fulfil one part of the office performed by the latter, namely, the collection of the current. They do not commute it, or adjust it in any way; hence there is no sparking between the rings and their brushes, except under the same conditions as there would be with any connecting-piece, namely, a loose joint.

Where the armature is stationary, as in the Mordey alternator, the leads to the external circuit are secured to terminals held by but insulated from, the frame of the machine; so that there can only be sparking there, if a connection is loose. This arrangement, however, necessitates the delivery of the exciting current to the field-magnet coils by means of a pair of collector-rings carried on the revolving shaft. These rings, in fact, take the place of the collector-rings of the armature, when the latter revolves, with the advantage that the current passing through them is smaller and at a lower pressure.

To furnish a certain electromotive force, whether in an alternator, or continuous-current dynamo, a certain product is necessary, the factors of which are:—(1) The strength of the magnetic field; or the number of lines of magnetic force in a given area of the magnetic field; (2) the number of conductors, or

turns of one conductor, passing through the magnetic field, that is to say, the number of active conductors on the armature: and (3) the speed of travel of the armature through the magnetic field.

The total output of an alternating-current generator is measured, as explained, by the product of the virtual or effective electromotive force by the virtual or effective current: that is to say, the total possible output of the alternating-current generator, when the power-factor is unity, or, $\phi$, the angle of lag is 0.

As in the continuous-current dynamo also, the largest current which can be taken from a given alternating-current dynamo is measured by the largest current that the armature-conductors will allow to pass without excessive heating, the largest virtual or effective current.

It is obvious, of course, that the given product required for a certain electromotive force may be made up in a variety of ways:—(1) The magnetic field may be very strong, and the speed of rotation and number of armature-conductors low; and (2) the magnetic field may be weak, and the number of armature-conductors and speed of rotation high: and there may be any variation of these.

Commercial requirements, however, rule that for a given output, a machine of a certain size and weight, and having therefore, if properly designed, a magnetic field of a certain strength, is the most economical. And, further, mechanical requirements rule, within certain limits, that a certain speed of rotation for an armature of a certain size and weight is safe. And so the question of the electromotive force and current resolve themselves, as in the continuous-current dynamo, into a question of the size of the conductors on the armature.

If the conductors be small, the current is also small, and if the machine be large the electromotive force will be proportionately high, and *vice versa*. This is to be understood always subject to the fact that while the effective electromotive force and current rule the largest possible effective output, the designer must provide for generating the maximum electromotive force, as already explained. Further, in some forms of alternator also, an additional source of loss by heat is introduced, by the to-and-fro motion of the molecules of iron in the armature, when the armature is built with iron cores to its coils.

The heating of the iron cores under this action—hysteresis, as it is termed—raises the temperature of the coils surrounding them, thereby reducing the margin of possible rise of temperature in the copper conductors, and the possible strength of the effective current. Many forms of alternators are, however, made without iron cores to the armature-coils.

Another possible source of additional heating, which, however, would be rarely met with in the armature-coils of the alternator, is the fact that, where reversals are frequent, only a portion of the conductor (the outside skin) takes any part in carrying the current, owing to induction between the individual portions of the conductor itself.

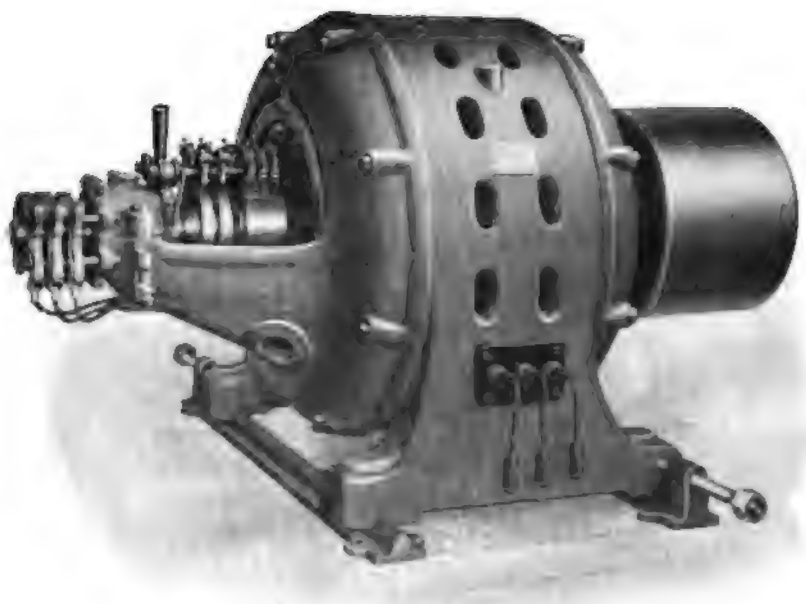

FIG. 14. - THOMSON-HOUSTON COMPENSATED ALTERNATOR, WITH REVOLVING FIELD-MAGNETS.

## XI.—REGULATION OF ELECTROMOTIVE FORCE WITH ALTERNATOR DYNAMO-GENERATORS.

The alternator dynamo-generator is not self-regulating, as the compound continuous-current machine is.

It will be remembered that with the compound continuous-current machine, the electromotive force at its terminals remains

constant, whether no current is being furnished external to the machine, or it is working up to its full load; provided that the speed is maintained constant. With the alternator-dynamo this is not so. As the current taken from the dynamo, the effective current, increases, the electromotive force at its terminals decreases, unless either the speed is increased, or the strength of the magnetic fields; and this decrease varies considerably, where the load consists of motors as well as lamps. It is usual, therefore, in certain stations to keep the speed constant, and to vary the strength of the exciting current, by means of an adjustable resistance, introduced into the exciting circuit, and worked by a switch. The arrangement is similar to that used with shunt-wound machines where, for special reasons, it is not desired to use a compound dynamo.

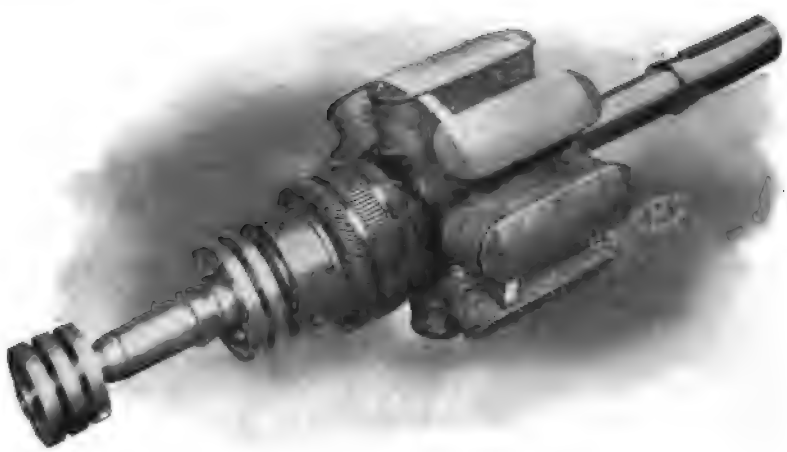

FIG. 15.—REVOLVING FIELD-MAGNET OF THE THOMSON-HOUSTON ALTERNATOR, WITH ARMATURE OF EXCITOR.

With a small load, the magnetic field is made comparatively weak. As the load increases, the field is strengthened, by switching out a portion of the resistance in the circuit of the field-coils. In making use of this arrangement, care must be taken that the resistance used is of such a nature that it will stand the passage of the current for hours together, without undue heating. This arrangement for regulating the magnetic field, or the alteration of the speed of the alternator-dynamo, rules for all kinds of alternators.

A form of automatic regulation has been adopted in the Thomson-Houston and Westinghouse alternators. The arrangement

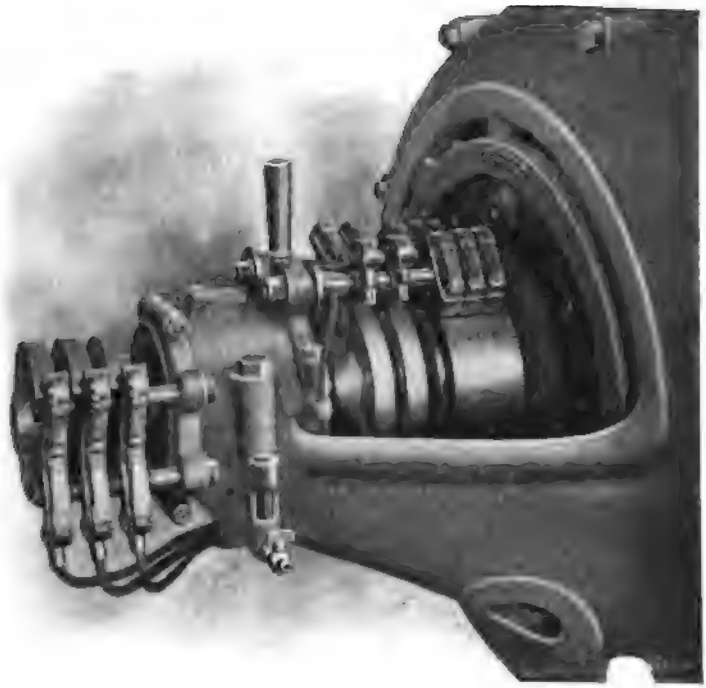

FIG. 16.—COMPENSATING MECHANISM OF THE THOMSON-HOUSTON ALTERNATOR.

of the latter is described with polyphase alternator generators. That of the Thomson-Houston is as follows:—The alternator itself is of the type in which the armature is stationary, and consists of coils held on the inside of an iron drum, as shown in Fig. 14. The field-magnets are formed by a star-wheel, as shown in Fig. 15, the magnet-poles being formed by the spokes of the wheel, the magnetizing coils being slipped over laminated iron spokes. On the same shaft as the field-magnets is also placed the armature of the continuous-current dynamo that is to furnish the exciting current for the field-coils of the alternator. The exciting dynamo is of the multiple type, its poles being of the

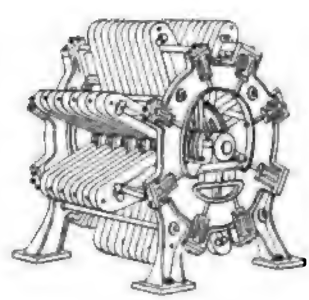

FIG. 17.—DE MERITENS ALTERNATING-CURRENT MACHINE, WITH PERMANENT MAGNETS.

same number as those of the alternator itself. The current from the armature is taken by a cylindrical sectional commutator with brushes, in the usual way, and it furnishes the necessary excitation for its own field-coils as well as to the field-coils of the alternator.

As usual in these cases, the exciting dynamo is series-wound, its external circuit being formed by the field-coils of the alternator. In addition to this, however, the shaft which carries the field-coils of the alternator, and the excitor armature, also carries

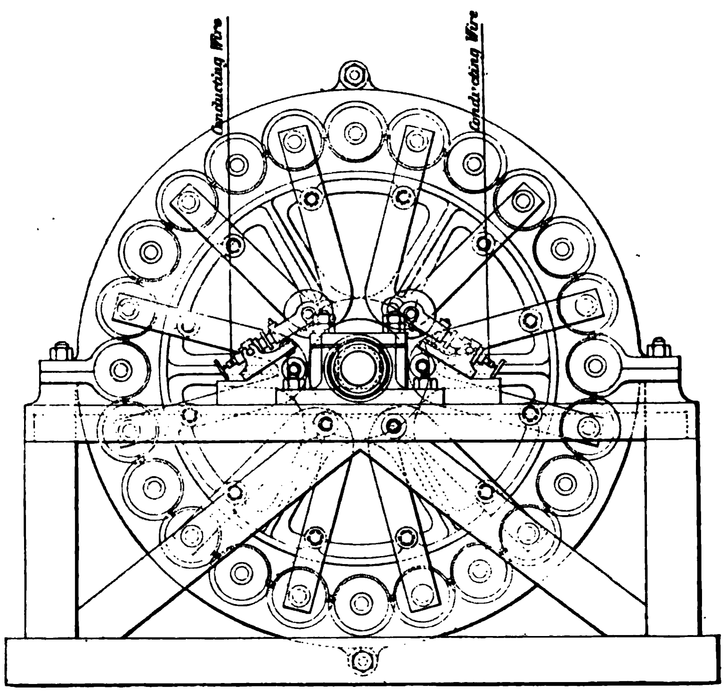


FIG. 18.—SIDE ELEVATION OF THE HOLMES MAGNETO-ELECTRIC MACHINE, WITH PERMANENT MAGNETS.

three collector-rings, connected to three points in the excitor armature, and also to certain transformers on the external circuit. The result is that the current furnished by the excitor, is modified by the work being done on the outer circuit. This will be dealt with more fully in the second part of this paper. Fig. 16 shows the arrangement of the excitor, with its commutator and special collectors.

The requisite number of alternations is accomplished in the following manner, in the simple, or single-phase alternator:—In place of the armature-conductors being wound on one ring, or one cylinder, they are divided into a number of coils of various forms and sizes, according to the fancy of the designer; and the field-magnets, in place of being in the form of one or two powerful horseshoe magnets, are also usually divided up into a number of smaller magnets, each one, or each pair producing its own magnetic field, but the whole of the coils form part of one system.

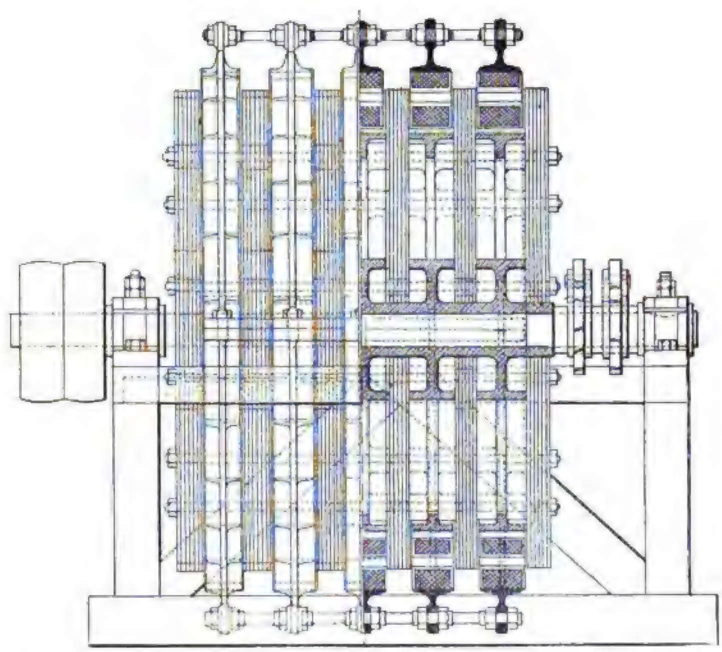

FIG. 19.—FRONT VIEW AND CROSS SECTION OF THE HOLMES MAGNETO-ELECTRIC MACHINE, WITH PERMANENT MAGNETS.

In a large number of types of alternators, the armature is in the form of a disc, made of a number of coils, of various forms, as mentioned above, and in other types of alternators the armature takes the form of a drum, something after the style of the continuous-current drum-armature.

In some types of alternators, the armature is stationary, in others it revolves. In either case, however, whatever the form, it is arranged that each coil of the armature passes through a succession of magnetic fields arranged so that the inductive action,

tending to generate electromotive force, is reversed at each field, and the reversals coincide with the period of the alternator: the passage of any individual coil, and of all the coils, through two consecutive magnetic fields, being coincident with and forming one complete period.

The number of cycles required is produced by the number of these fields, multiplied into the number of revolutions per minute or per second. Thus, if there be eight magnetic fields, through which the armature-coils pass, there will be eight reversals or four

FIG. 20. – SIEMENS SINGLE-PHASE ALTERNATOR, EARLY TYPE.

complete cycles at each revolution whether of armature or field-magnets; and if the machine is being driven at a speed of 1,500 revolutions per minute, there will be 6,000 complete cycles per minute, or 100 per second.

In very early types of alternators, permanent magnets were employed, held in circular frames, and coils of wire, very similar to those used for electric bells, revolved in front of the magnet-poles. But as all permanent magnets tend to lose their magnetism gradually, and therefore to lessen the output of the machine, and as also the size of machine that could be constructed with

permanent magnets was strictly limited, this method was abandoned as soon as the continuous-current machine had shown that powerful electromagnets could be constructed.

A large number of permanent magnet alternators, of the Holmes and De Meritens types were used, however, for lighthouses, and the writer believes that a few are still in use. Fig. 17 shows a De Meritens machine; Figs. 18 and 19, a Holmes machine; Fig. 20 shows one of the earliest electromagnetic alternators, the Siemens; and Fig. 21, a Siemens single-phase alternator, of modern type.

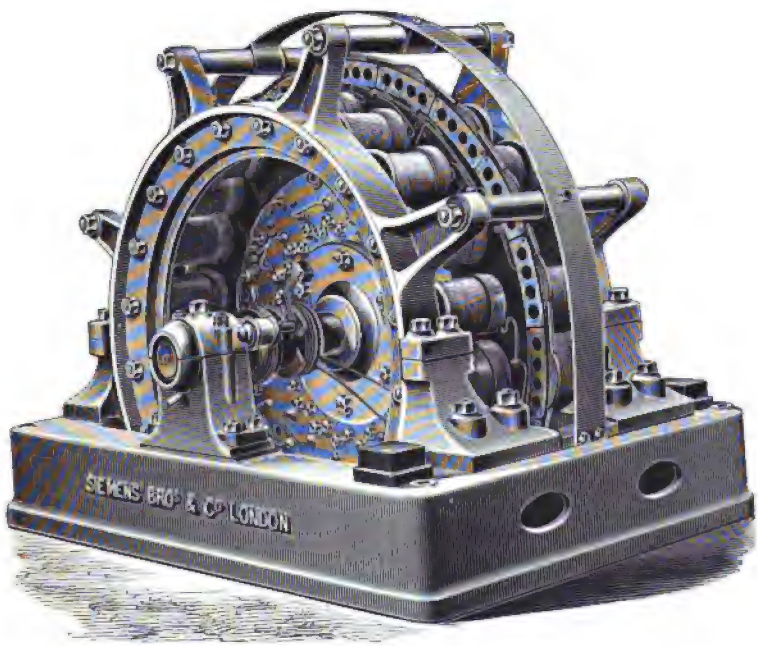


FIG. 21.—SIEMENS SINGLE-PHASE ALTERNATOR, MODERN TYPE.

It will be noticed, by those who have had the opportunity of seeing large Siemens alternators in central electric-lighting stations, that the form of this machine has not changed. It consists of two circles, or crowns of electromagnets: the latter being held horizontally by annular iron discs arranged vertically. The electromagnets consist merely of coils of wire, wound upon cylindrical iron cores. The electromagnets are so arranged in this machine, that the poles alternate N, S, N, S, all round each

crown, while unlike poles face each other, the alternations in the two crowns of magnets being oppositely arranged. Therefore, between each pair of magnets facing each other is a magnetic field, and the direction of the magnetic force in each of these fields alternates round the circle.

By the direction of the magnetic force is meant either the direction in which the north-seeking end of a freely suspended magnetic pole will turn when held within the magnetic field, or the direction of the electric current set up in a conductor through the field, moving at right angles to the direction of the lines of force.

Looking at the periphery of the alternator, it will be seen that there are a succession of highly magnetized spaces passing round the circle. Within the vertical space left between the two crowns of field-magnets, the armature is suspended on its spindle, the latter being supported in bearings, on the outside of the field-magnets on each side. The armature, in this case, consists of the same number of coils of wire, as there are magnetic fields, or as there are field-magnets in each crown.

The coils are made without iron cores, and are of the form that they would naturally take to fall into the annular space allotted to them in the armature, smaller on the inner radial side. Necessarily also they are flat. In the earlier forms of Siemens alternators the armature-coils were made of wire of the required gauge. In the later and larger forms they are of strip-copper.

In the earlier forms also, the coils were carried by a wooden disc, through which the spindle passed. In the later and larger forms, a steel disc carries the coils on its periphery, and the spindle at its centre, the coils being insulated from the disc.

As each coil passes through the space between the opposing poles of the field-magnets, it generates an electromotive force; the electromotive forces generated by each coil being added together to make the total electromotive force delivered at the terminals of the machine, as with the coils of the continuous-current dynamo.

After passing between one pair of poles, as the coils pass through the next set of magnetic fields or spaces, in succession, an electromotive force is created in each coil, in the opposite direction to that created in them when passing through the previous spaces, and its direction is again reversed when passing through the next spaces, and so on.

It will easily be understood that, as the strongest part of the magnetic field present between each opposing pair of magnetic poles, will be on, or nearly on the line passing through the centres of their iron cores; and as also the wires or turns of strip, of which the coils are composed, come gradually into the field, and pass gradually out of it, more and more turns being cut by more and more lines of force in passing into the field, and the

FIG. 22.—ARMATURE OF THE FERRANTI ALTERNATOR.

reverse on passing out, the electromotive force created will increase gradually to a maximum, and again decrease gradually to zero, again increasing gradually to a maximum with the reverse sign, in the manner already described.

But a very important point requires explanation here. If the coils generate electromotive forces of opposite name, in passing through each succeeding magnetic field, how comes it that the

electromotive forces created by alternate coils do not neutralize each other? It is avoided by the following arrangement. Alternate coils are oppositely wound, with reference to the direction of motion; or what amounts to the same thing, and is usually the arrangement, the coils are all wound alike, but alternate coils are oppositely connected, so that, though the electromotive force created is in the reverse direction with reference to the direction

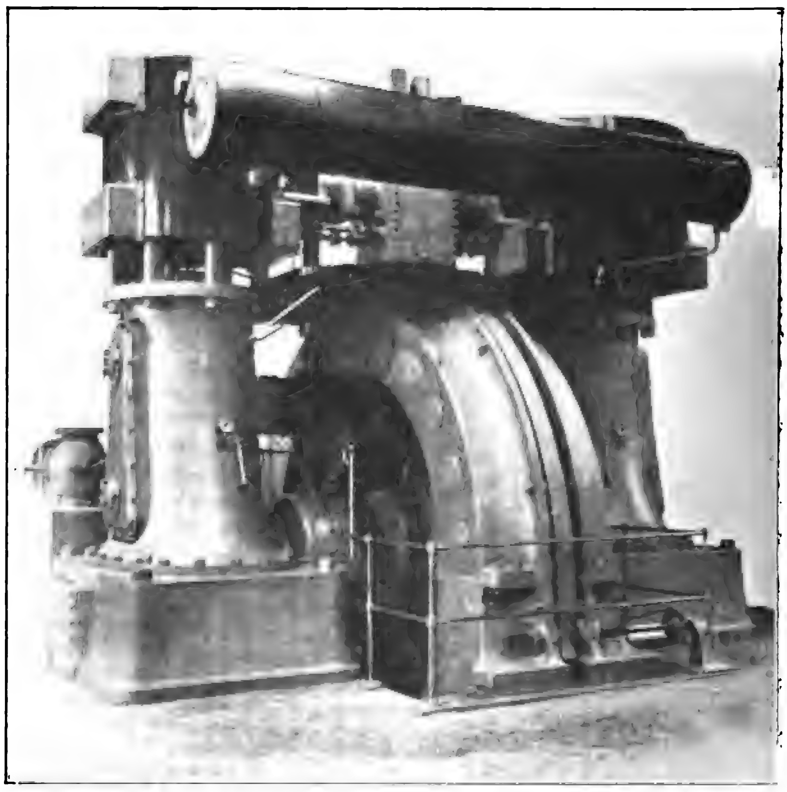

FIG. 23.—FERRANTI FLYWHEEL ALTERNATOR.

of motion, by the arrangement of the connections of the coils, the actual electromotive force is of the same sign in all the coils with reference to the external circuit.

The arrangement of the coils was seen very clearly in the early Ferranti armature, which was a development of the Siemens armature. The armature was made in the form of a star, and from one

continuous copper strip without break. When the outer portions of the star were passing between one set of pairs of poles, say, with their N poles on the left, the inner portions were passing between the other pairs of poles having their S poles to the left, and so the electromotive forces created were opposite in name with reference to the direction of motion, but by the arrangement of the coils they were added together as before. In the later Ferranti armature, shewn in Fig. 22, the coils are wound upon cores of laminated brass,

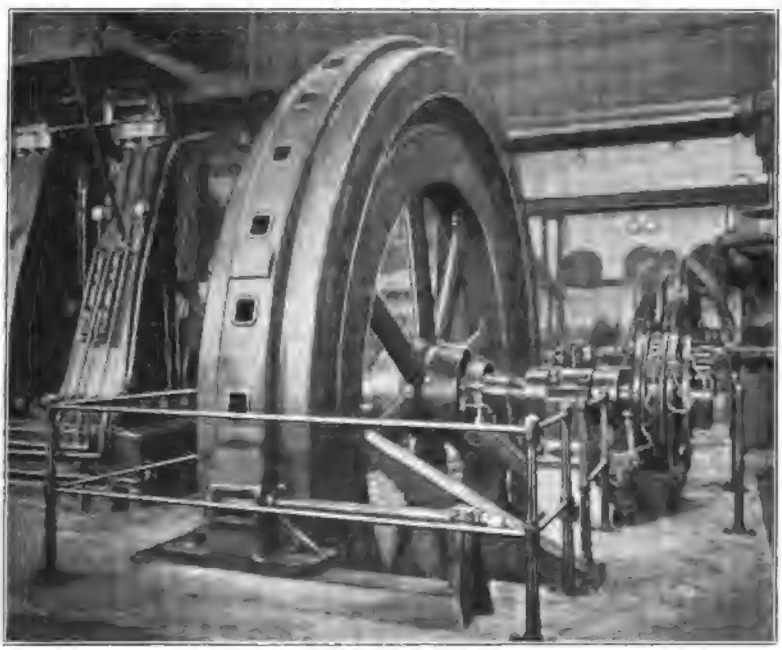

FIG. 24.—FLYWHEEL DIPHASE ALTERNATOR OF THE ELECTRIC CONSTRUCTION COMPANY, WITH DIRECT-COUPLED EXCITOR-DYNAMO.

the conductors being of corrugated copper strip, wound on by special machinery, with a strip of insulating material between.

Fig. 23 shows one of the later, complete Ferranti flywheel alternators. That is to say, in this machine, the revolving portion of the alternator-dynamo actually forms the flywheel of the engine driving it. The engine is of the compound type, the two cylinders being arranged vertically and inverted, one on each side of the flywheel. The field-magnets are, as before, arranged in two vertical crowns, secured to heavy iron annular discs, which are bolted

to the framework of the engine. Through the centre of the field-magnet discs, and concentric with them, passes the armature-shaft, which is also the crank-shaft of the engine carrying a flywheel, upon which the armature-coils are fixed.

Another type of flywheel alternator-dynamo made by the Electric Construction Company is shown in Fig. 24. The engines are as before, of the compound type. In this case, the

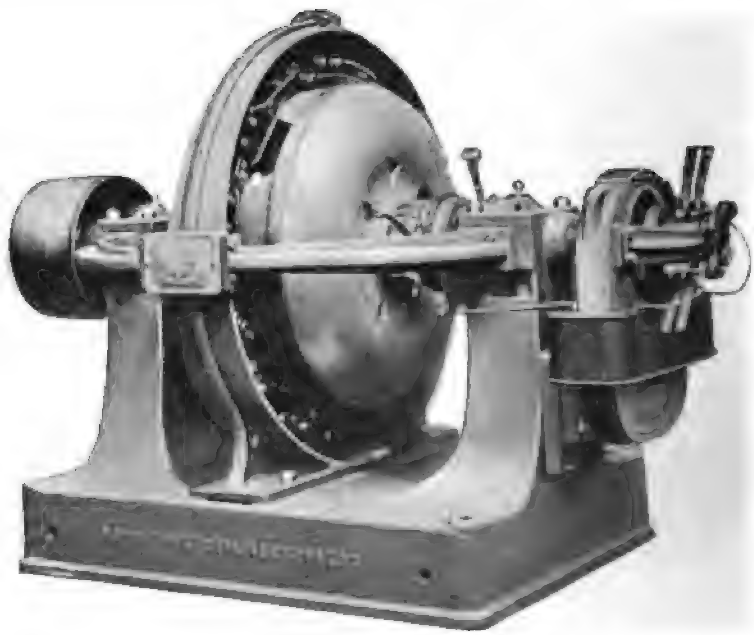

FIG. 25. – MORDEY ALTERNATOR.

field-magnets are carried by a drum outside the flywheel, the coils projecting radially inwards, and the armature-coils are carried on the periphery of the flywheel.

Another type of alternator-dynamo, of which a great many have been made, and are in use, and in which a new departure was made, is the Mordey alternator, shown in Figs. 25, 26 and 27. In the Mordey alternator, only one electromagnet, strictly speaking, is employed, but it has a number of arms, the claw-like projections which are shown embracing the armature-coils. The armature-coils are arranged in the form of an annular disc, and are

held in the centre of the machine longitudinally. Through the central space in the armature passes the main portion of the field-magnet, consisting of a single cylindrical bar of iron, or the special magnet-steel now made, with its exciting wire-coil. From the ends of the field-magnet project the driving shaft, going to its bearings, and the claws mentioned above which curve round, from both ends to the centre, where they nearly embrace the armature-disc. Cast-iron covers protect the claws from the air-friction that they create, when revolving, and an extension of the field-magnet shaft also carries the armature of the continuous-current exciting dynamo, whose field-magnets, brushes, etc., are supported by a projection from the general framework of the machine. The claw-like projections of the field-magnets are its pole-pieces; but, unlike other alternators, all on one side of the armature-disc

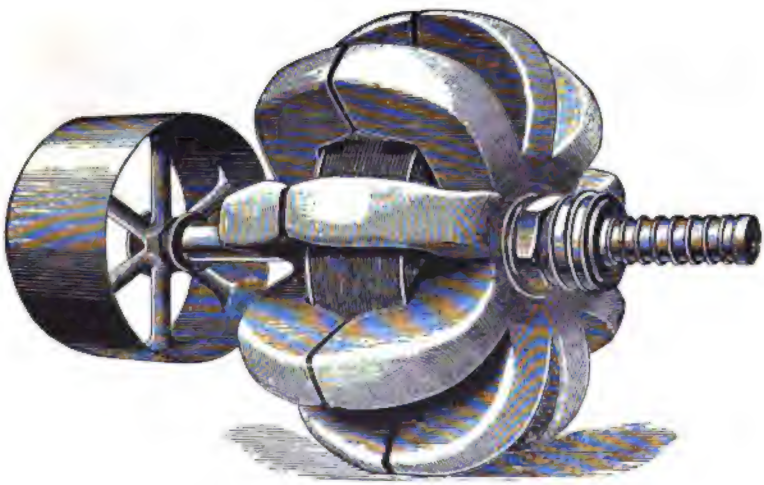

FIG. 26. — FIELD-MAGNET OF THE MORDEY ALTERNATOR.

are N poles, while all on the other side are S poles. The direction of the magnetic field is thus the same all the way round, but its strength is greatest on lines joining the centres of opposite claws. The rise and fall of electromotive force and current are produced, in this alternator, by the approach to and recession from each coil, of the pairs of claws, and the reversals are produced by having twice as many coils as there are pairs of poles, or claws, and connecting the wires of alternate coils, the reverse way, as in the other forms of alternators. As a pair of poles approaches

an individual coil, the electromotive force gradually increases in that coil, till the centres of the coil and of the pole-pieces coincide, when the maximum is reached. As the poles pass on, the electromotive force gradually decreases, till the line of junction with the next coil is reached. That coil now takes up the generation, the electromotive force again increasing, but in the opposite

FIG. 27. – ARMATURE OF THE MORDEY ALTERNATOR.

direction, and so on. The current generated follows on the generation of the electromotive force, when the induced electromotive force allows it, as already explained. Everything else follows as with other alternators.

## XII.—THE INDUCTOR-ALTERNATOR.

It is but a step from the Mordey alternator to the Mordey, or any other inductor-alternator. It will be remembered that, in

order to generate an electromotive force in any conductor whether in a continuous-current dynamo, or an alternator, or under any other conditions, by electromagnetic induction, it is necessary that there shall be a change in the magnetic field in which the conductor is, or as it is expressed, a change in the number of lines of force passing through the conductor. And it will also be remembered that this change can be produced either by (*a*) motion of the conductor through a magnetic field; or (*b*) motion of the field past the conductor. A modification of (*b*) is, by alteration of

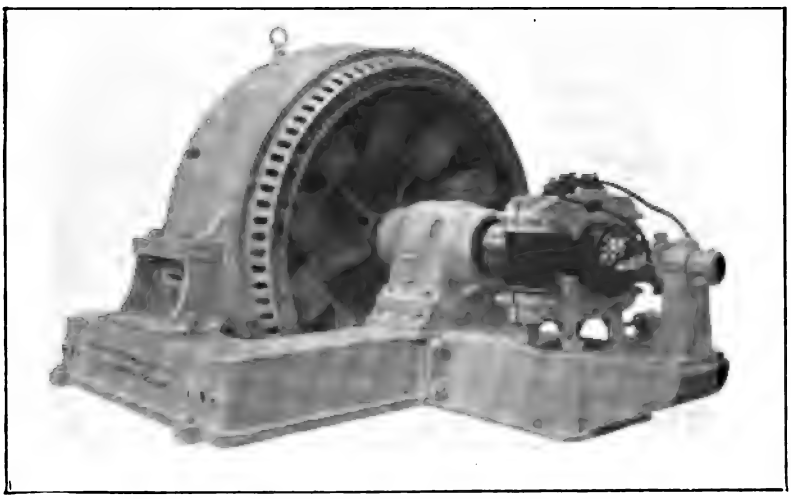

FIG. 28.—MORDEY INDUCTOR-ALTERNATOR.

the arrangement of the magnetic field, of the iron forming part of the magnetic circuit. And this is the plan adopted in the inductor-alternator: masses of iron only revolving; the conductors both of the exciting coils of the field-magnets and of the armature remaining stationary.

The inductor-alternator usually takes the form of an outer drum, or wheel, of iron, with teeth projecting inwards, these latter being made up of iron plates, and with a star-wheel concentric with it, revolving inside the drum. On the teeth of the drum are carried the field-magnet coils, and also the armature-coils. In some forms of inductor-alternators, these are placed on alternate teeth, field-magnet, armature, field-magnet, armature, all round the drum. In others, notably in the Mordey, the

field-coils occupy all the teeth, the armature-coils being placed in slots between the teeth.

Figs. 28, 29, 30, 31 and 32 show the Mordey inductor alternator. Fig. 28 shows the complete machine; Fig. 29 shows the outer drum, with its teeth and the spaces for the armature-coils: Fig. 30 is a sectional elevation of the complete machine; Fig. 31 is a vertical transverse section showing the arrangement of the field and armature-coils; and Fig. 32 shows the revolving star-wheel. The rationale of the machine is as follows:—When any radial arm of the star-wheel is opposite any portion of the outer drum, the magnetic resistance between these two surfaces is at its lowest figure, and the lines of force passing across the intervening space, at their highest. As the radial arm moves onward, the magnetic resistance at the place that it has just left gradually increases, the lines of force decreasing,

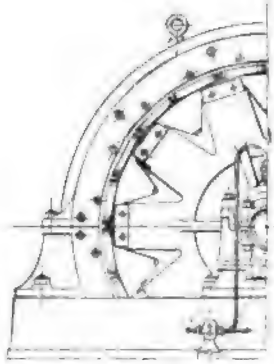

FIG. 29. - OUTER DRUM OF THE MORDEY INDUCTOR-ALTERNATOR, WITH TEETH AND SPACES FOR ARMATURE-COILS.

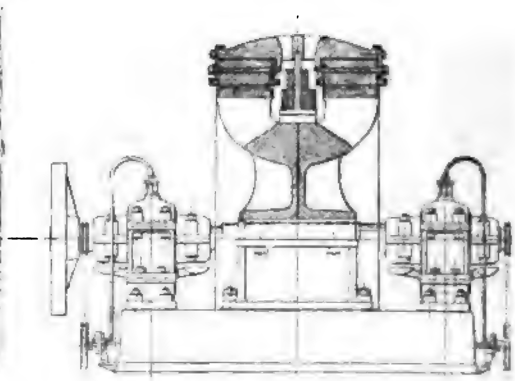

FIG. 30. —SECTIONAL ELEVATION OF THE MORDEY INDUCTOR-ALTERNATOR.

till the next arm approaches, and so on. Each armature-coil, in its recess, experiences this increase and decrease of the lines of force passing through it, as each arm of the star-wheel approaches and recedes: with the result that an electromotive force is created in each coil, increasing and decreasing as the radial arm approaches and recedes. Reversal is produced by the same method as in the Mordey alternator, namely, by having double the number of armature-coils that there are arms in the star-wheel, and arranging the winding, or the connections of half of

the coils oppositely to the other half. The star-wheel then generates, say a positive current in one set of coils, rising and falling as in all cases, then passes on and generates a current in the other set, in the opposite direction, also rising and falling. All the coils are in one continuous circuit, and the electromotive force delivered at the terminals of the machine is the algebraical sum of all the electromotive forces generated at each instant.

The number of cycles produced by the inductor-alternator is found, as with the ordinary alternator, by multiplying the number of pairs of poles, the number of arms in the star-wheel, by the number of revolutions in a minute, or second.

The arrangement of the design, so that each coil shall furnish its maximum and its effective electromotive force, at any given speed, is found by calculation, as in other dynamos.

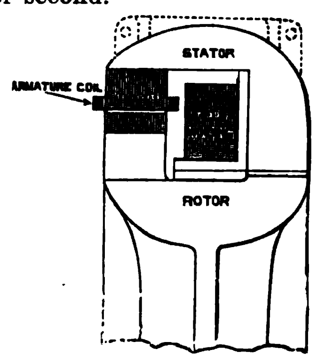


FIG. 31.—TRANSVERSE SECTION OF THE MORDEY INDUCTOR-ALTERNATOR, SHEWING THE ARRANGEMENT OF THE ARMATURE AND FIELD-COILS.

The current passing in the circuit or circuits fed by inductor-alternators follows the laws governing alternating-currents furnished by alternator-dynamos of the ordinary pattern. It will be noticed that there are no sliding contacts in this machine, all the connections, both to armature-coils and exciting field-coils, being made to fixed terminals.

## XIII.—DIPHASE AND TRIPHASE ALTERNATORS.

The only difference in principle, between the simple alternator (as it is usually called in France), the single-phase alternator (as it is more frequently termed in this country and America), and the diphase and triphase alternator, is that the latter are arranged to furnish two or three currents, while the former only furnishes one current.

Where the arrangement of the armature-coils of a single-phase alternator is such that there is sufficient space between each adjacent pair of coils to place other similar coils, the provision of these coils, and their connection to separate collecting-rings, converts the apparatus into a diphase alternator, furnishing two

sets of electromotive forces, and two sets of currents, which can be used as required, in two separate circuits. It must be remembered, however, that as the machine will now be doing twice as much work as it performed as a single-phase alternator, the engine driving it must be capable of delivering twice the mechanical energy to its driving shaft that was delivered to the single-phase machine, and the strength of the other parts must be in proportion. The rationale of the diphase machine will be as follows:— An individual coil, belonging to one of the sets, will approach one of the spaces described in the single-phase alternator as being one across which the lines of force are very dense; it will pass through this space, and on to the next, generating in its passage a gradually increasing and then gradually decreasing electromotive force, then reversing, and so on, just as the single-phase machine

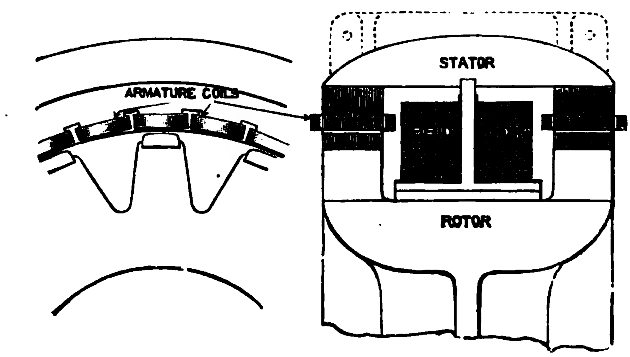


FIG. 32.—REVOLVING STAR-WHEEL OF THE MORDEY INDUCTOR-ALTERNATOR.

does. As the coil passes the centre line of that field, and the electromotive force commences to fall, the coil behind it, belonging to the other, will come within the influence of that field and will commence to generate an electromotive force, which will rise, as that of the first coil falls, till the electromotive force in the first coil reverses its sign, that in the second coil arrives at its maximum, and begins to fall in its turn.

As this happens, the coil next behind again enters within the influence of the same field, an electromotive force being generated in it, gradually rising as that in the second coil is falling, and as that in the first coil is also rising, in the next field, and so on: the proper arrangement of electromotive forces and currents in the sets of coils being provided for by the winding or connections of the alternate coils of each set.

The above shows, pretty clearly, the principle upon which diphase alternators are constructed; and if three sets of coils be supposed to be arranged, in the manner described for two sets, the time occupied by the three sets being divided equally between them so that the second set commences to generate an electromotive force, when the first has passed through one third of its

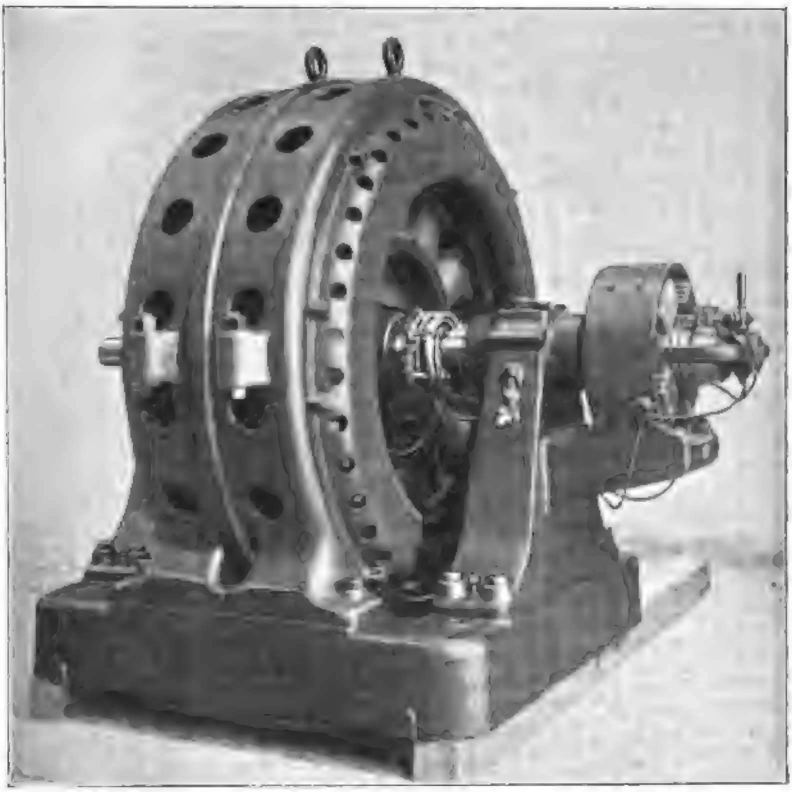

FIG. 33.—BROWN-BOVERI TRIPHASE ALTERNATOR.

complete cycle, or has reached its first maximum and fallen one third towards its second zero; the third set following when the second has reached the point that the first had reached when the second started, and so on, these divisions being respectively one third and two thirds of the total angular space occupied by two magnetic fields, then we have the triphase, or polyphase alternator.

In practice, the following lines have been followed in a

great many cases. The armature is stationary, and consists of an iron drum with two or three sets of coils on its inner surface; the number of coils being twice, or three times the number of pairs of poles, according as the machine is to furnish two, or three currents. The field-magnets revolve inside the drum, their poles being brought as close to the armature-coil as the safety of the machine will allow. The field-magnets are arranged something on the lines of the star-wheel of the inductor-alternator described above; but there must be pairs of poles to create a changing magnetic field in the space occupied by each armature-coil in succession, as the magnetic poles revolve.

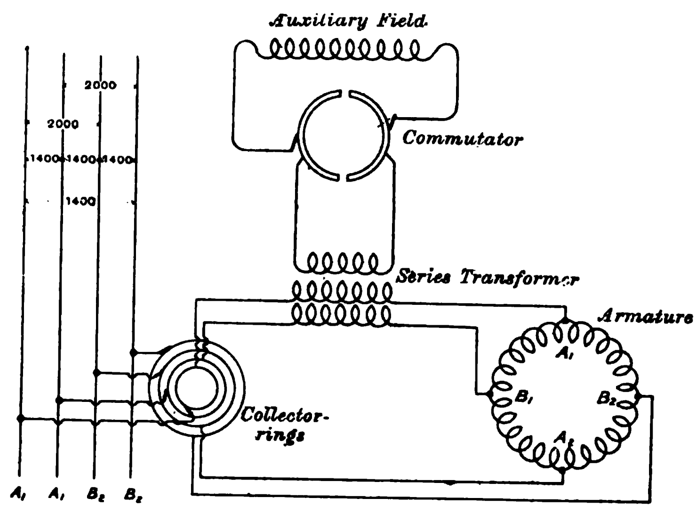


FIG. 34.—DIAGRAM ILLUSTRATING CONNEXIONS FOR WESTINGHOUSE DIPHASE ALTERNATORS.

There are various methods of accomplishing this. One of the most beautiful, and at the same time the most economical, was that designed by Mr. Brown, of Baden in Switzerland, for the machines used for the celebrated Lauffen-Frankfort 100 miles transmission, at the Frankfort exhibition. The field-magnet of the Brown polyphase alternator-generator used at Lauffen consisted of a disc of iron, mounted on a driving shaft, and having its periphery divided up into teeth, as many teeth as there were magnet-poles. The teeth were the pole-pieces.

Fig. 33 shews the latest form of triphase alternating-current

generator, designed by Mr. Brown, and many of them are in use in this country.

In Westinghouse diphase and triphase alternator-generators, the field-magnets are stationary, and are held radially projecting inwards, from an iron drum, the armature revolving in the cylindrical space remaining.

The armature consists of a number of plates of iron, or special soft steel, strung on a driving hub and spindle, to form a cylinder, and with slots milled out of the cylinder, longitudinally, in which the armature-coils are placed.

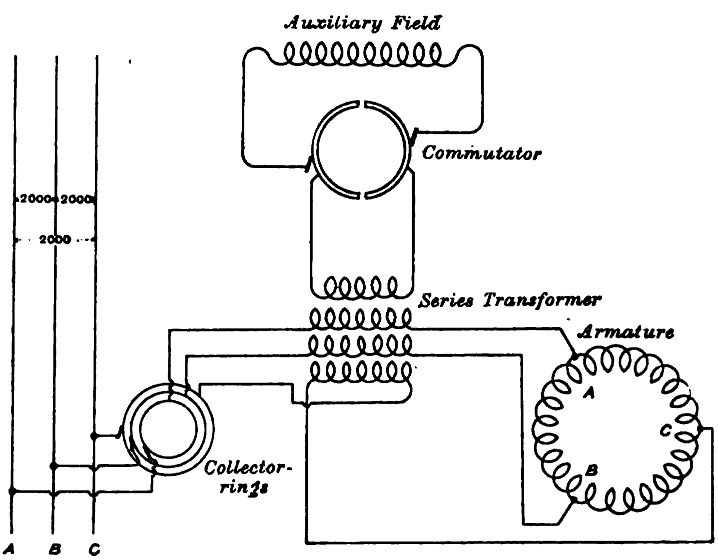


FIG. 35.—DIAGRAM ILLUSTRATING CONNEXIONS FOR WESTINGHOUSE TRIPHASE ALTERNATORS.

The coils form one continuous winding, as in the continuous-current dynamo; but in place of the commutator used with the continuous-current machine, three or four collecting-rings, insulated from each other, and from the driving-shaft, are carried by the latter, and are connected to certain points in the armature-winding. With the diphase machine, there are four collecting-rings, and four points of connection in the armature-winding, each ring being connected electrically with one of the four points. The collecting-points are situated at intervals of 90 degrees, round the armature. With the triphase machine, there are three

collecting-rings, and three points of collection, 120 degrees apart, in the armature-winding, to which the rings are connected.

The excitation of the field-magnets of the Westinghouse diphase and triphase alternator-dynamos is also arranged in a special manner as shown in Figs. 34 and 35.

There is the usual exciting current supplied by a continuous-current dynamo; and in addition, in all machines of less than 300 kilowatts. machines capable of furnishing current for 5,000

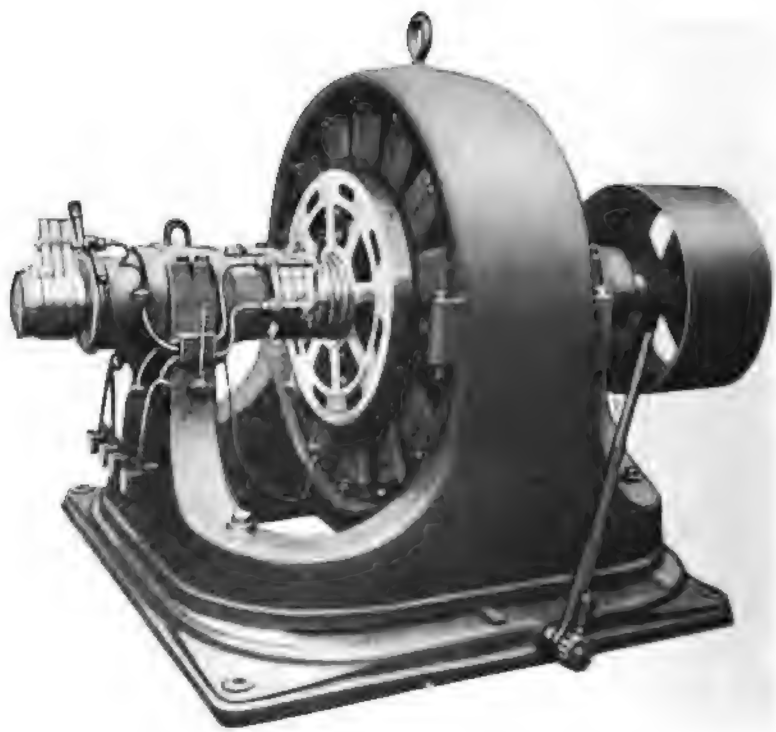

FIG. 36. – WESTINGHOUSE POLYPHASE ALTERNATOR.

lamps of 16 candlepower, the field-current supplied by the separate continuous-current dynamo is supplemented by a current from the armature of the alternator itself, much as a continuous-current machine does; but in a special manner.

The current taken from the collecting-points in the armature-winding passes on its way to the collecting-rings, through transformer-coils carried by the driving spokes of the armature. The secondary coils of these transformers are connected to commutat-

ing semicylindrical rings carried by the armature-shaft, and to these rings also are connected the ends of the auxiliary coils of the field-windings.

The semicylindrical commutators arrange the currents received from the transformer-coils, all in one direction, though they still rise and fall in strength, and the transformer-coils deliver the

FIG. 37.—FIELD-MAGNET DRUM AND FIELD-POLES OF WESTINGHOUSE POLYPHASE ALTERNATOR.

currents at the pressure at which the field-coils can make use of them. The object of this arrangement, which is somewhat similar to that used in the Thomson-Houston alternator-generator, is to increase the strength of the magnetic field, as the current supplied by the generator, the effective current, increases and so to raise the electromotive force, the effective electromotive force

delivered at the terminals of the different circuits, at the different terminals of the dynamo.

Fig. 36 shows the complete Westinghouse polyphase generator, Fig. 37, the field-magnet drum with its field-poles projecting radially inwards, and Fig. 38 the armature.

FIG. 38.—ARMATURE OF WESTINGHOUSE POLYPHASE ALTERNATOR.

The construction is exactly the same for monophase, diphase and triphase machines, the only difference being in the number of collecting-rings, and the number of points of collection, as already explained. Figs. 34 and 35 show the arrangement of these connections.

It will be understood, that, with a diphase, or triphase machine of a given size and weight, the output, the total quantity of mechanical energy converted into electrical energy, is, for practical purposes, the same as if the machine had been a simple alternator.

A diphase machine may be considered, in fact, for practical purposes, as a simple alternator, with the current delivered in two circuits instead of in one; while in the triphase, the current is delivered in three circuits instead of one; but the total quantity of electrical energy is only twice that generated in each phase. The currents in each circuit, when working with diphase or triphase currents, are always kept, as far as practicable, equal in quantity. With the diphase generator, each circuit is kept quite distinct from the other, four wires being employed to deliver the two currents. With the triphase, only three wires are employed, the arrange-

ment being such that one of them always acts as a return for the other two, each taking this office in turn. Four wires may be used with triphase currents and three wires with diphase currents, by altering the arrangement of the return-circuits, but the plan usually adopted is as stated above.

All this will be explained more fully, when dealing with the conversion of the energy of alternating currents into mechanical energy.

The energy delivered to each circuit at any moment is measured by the product of the effective electromotive force at the terminals of the generators for that circuit, multiplied by the effective current passing in that circuit, and multiplied again by the cosine of the angle by which the current lags behind the electromotive force in that circuit.

The losses due to friction are divided between the circuits; but each circuit has to bear the loss incurred in itself by its own self-induction, and by the mutual induction between itself and the other circuits: the sum of all these making up with mechanical friction, air-friction, loss by conversion of current into heat in the coils, loss by heating of the iron due to the molecular motion in reversals of magnetism, etc., the total charge for conversion from mechanical to electrical energy made by the machine.

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Mr. SOPWITH, in proposing a vote of thanks, said that Mr. Walker's previous papers had practically been his own text-books on the subject of electricity, and if this paper was on the same lines as that contributed some years ago to the North of England Institute of Mining and Mechanical Engineers* it would be a very valuable addition to their *Transactions*.

Mr. M. WALTON BROWN seconded the vote of thanks, which was cordially approved.

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Mr. JOHN KIRSOPP read the following paper on "The Coal-fields of Cook Inlet, Alaska, U.S.A., and the Pacific Coast":—

* *Trans. N.E. Inst.*, 1884, vol. xxxiv., page 3.

# THE COAL-FIELDS OF COOK INLET, ALASKA, U.S.A., AND THE PACIFIC COAST.

By JOHN KIRSOPP, Jun.

## I.—Introduction.

Alaska belonged to Russia until it was sold to the United States in 1867.

*Cook Inlet.*—The Cook Inlet coal-field, situated between latitudes 59 and 62 degrees north and on longitude 151 degrees east, on the northern shores of the Pacific Ocean, comprises at least five detached areas of Tertiary beds containing lignites (Figs. 1, 2 and 3, Plate XVI.). The region, comprising the south-eastern shores of Cook Inlet and including the Kachemak Bay area of the field, was examined by Dr. W. H. Dall, of the Geological Survey of the United States,* but, owing to the limited time at his disposal, he seemingly confined his attention to the coal-seams seen outcropping in the bluffs between the point of Homer Spit and the head of Kachemak Bay, namely, the only portion of the coast or country where any prospects were then or had been under operation; † ignoring the outcrops of superior-looking lignite-seams in the bluffs to the westward of and between Homer Spit and Anchor Point at the entrance of Kachemak Bay.

These lignite-seams occur in what is known as the coal-bearing Kenai beds, best seen in the bluffs along the northern shores of Kachemak Bay, but occurring also in British Columbia and over the coast of Alaska and adjacent islands. These seams were regarded by Dr. Heer, and until very recently by other geologists, as being the equivalent of the Atane leaf-beds of Greenland, the Spitsbergen Miocene plant-beds, the brown coal of Eastern Prussia and the Lower Rhine provinces, and the Lower Molasse of

* *Seventeenth Annual Report of the United States Geological Survey*, 1895-96, part. i., pages 763 and following.

† Owing, presumably, to the shore in this section of the coast being more sheltered from the heavy seas running from the inlet, and less shallow than elsewhere along the coast, and thus more easily approached by boats.

Switzerland. Sir William Dawson and others now generally admit that the floras of the Upper Laramie of the Atanekerdluk Series in Greenland, and of the Spitsbergen and Alaskan Tertiary beds, correspond with the Eocene of Europe, and are also identical with the Fort Union flora of the Missouri region, formerly regarded as Miocene.

*Kachemak Bay.*—The accompanying section (Fig. 9, Plate XVII.), of the occurrence of lignite-seams in the bluffs on the north-western shore of and between Anchor Point, or the mouth and the head of Kachemak Bay, a distance of 35 miles, taken and prepared by the writer, includes a thickness of 2,683 feet of measures, containing at least 126 feet of lignite, in seams over 2 feet thick. It is possible, however, that this thickness is exaggerated, either owing to faulting (although there is no evidence of this in the face of the bluffs) or to the seams running in rolls. But the seams lying westward of Homer Spit present a different character, and are more compact in appearance than those eastward of that point, and this tends to show that they form a distinct series. The section neither begins at the top of the coal-bearing measures (a seam of inferior lignite, 3 feet thick, having been discovered 15 miles up Sheep creek and Forks river, at the head of the bay, and about 200 feet above sea-level), nor does it reach the bottom lying upon an older formation, as coal is washed ashore from the south-westward at Anchor Point.

Dr. Dall states that this area of the coal-field extends over a length of 70 miles and a width of 30 miles; but it is probably greater, as patches of what appear to be Tertiary beds, containing dark, carbonaceous streaks, are found on the southern and opposite shore of the bay. The range of mountains occupying this side is composed for the most part of schistose or crystalline rocks, forming the backbone of the Kenai peninsula, across which at least four high glaciers may be seen reaching almost down to the bay.

It is reported that coal was worked by the Russians on the south side of the bay, at Port Graham or English Bay, previous to the country being ceded to the United States; but as a consequence of the disturbed condition of these beds, mining operations were rendered difficult on account of frequent faults; and, moreover, the sulphur contained in the coal rendered it destructive to boiler-tubes and grate-bars. So although it was superior

to the Mount Diablo coal of California, yet as better coal became available by the opening of mines in British Columbia, Oregon and Puget Sound (after the transfer of the country to the States), these mines were finally abandoned.

Another area on this side of Kachemak Bay occurs to the north-east of the harbour of Soldovia, where the rocks are schistose and much contorted. In gaps between the projecting points are patches of apparently Tertiary beds, lying nearly horizontal, abutting unconformably on the schists, and containing dark, carbonaceous streaks. Midway between Soldovia and Yukon Island, about 40 feet above the beach-level, a seam is seen in the bluffs of the following section: Coal, 2 feet; clay and dirt, 4 feet; and coal, 1 foot. This seam is overlain by about 160 feet of sandstone and clay. Both of these coal-beds appear to be of as good a quality as any found in this coal-field, the lower one being of duller appearance, very similar to cannel-coal, and almost identical with the lower coal-seams cropping out in the bluffs on the opposite shore of the bay, 3 or 4 miles to the south-east of Anchor Point. An Indian told the writer that he could mine 5 tons in 3 days, and was paid 16s. 8d. per ton for it by the store-keepers at Soldovia. This patch is, however, very limited in area, and between it and the head of the bay on the southern shore, the surface-rocks are all schistose; in fact, the few patches of Tertiary beds on this side occur only in very limited areas, and are consequently of little economic value.

Coal also occurs in the valley of Sheep creek and Forks river, where an inferior seam, 3 feet thick, has been discovered about 15 miles inland from the head of the bay. Northward and westward of this valley, the character of the country changes, being overlain by Tertiary beds, and the surface of the ground, instead of being bare and mountainous, and covered with snow all the year round, is thickly mantled with long Hungarian grass and clumps of spruce.

The coal-outcrops are more or less exposed and discernible along the northern shores of the bay, and can be traced to within 3 miles of Anchor Point, the mouth of Cook Inlet. Rounding this point, the coal-outcrops are again exposed in the bluffs, 6 miles farther up the inlet, whence they can be traced northward.

At Nielchic, the bluffs are slightly over 100 feet high, showing one thick seam and several thinner ones, which may be traced to within 8 miles of Cape Kassilof.

At Cape Kassilof, the bluffs are 75 to 100 feet high, exposing clay and gravel beds, but no coal-seams. Northward past Kenai, the coast is that of a low-lying country, the inland hills (of slate formation) being 10 to 20 miles back, and this continues northward to Chickaloon Bay at the mouth of Turnagain Arm, near the extreme north of Cook Inlet. On the southern side of Turnagain Bay are situated two placer-gold mining-camps, lying on a granite-and-quartz formation namely, Hope City, with about 40 white inhabitants, and Sunrise City, situated 9 miles higher, with 150 winter inhabitants. At the latter place, they are mining to a depth of 25 feet below high-water mark, and there are six hydraulic plants at work. Up to the present, however, more money has been taken out of Bear creek, near Hope City, than elsewhere in the locality.

According to Mr. George H. Eldridge,* the Kenai formation, containing coal-beds, has been encountered in three areas on the western or opposite side of Cook Inlet, namely:—(1) at Tyonek; (2) on the eastern bank of the Sushitna river, 1 mile below the mouth of the Yentna; and (3) on the main fork of the Sushitna, 4 to 10 miles above the mouth of the Chulitna.

*Yentna.*—Little can be learned of the Yentna area without boring, or other extensive prospecting. One or two small coal-seams in a limited outcrop of clays and sandstones, with a conglomerate of undetermined relationship near by, are all that can be seen.

*Sushitna River.*—The area on the main fork of the Sushitna river appears in outcrop for a distance of 6 or 7 miles, and is, perhaps, the exposed portion of a large deposit. This strata, forming bluffs, 100 to 300 feet high, consists of clays and sandstones, the former predominating, with coal-seams varying from 6 inches to 6 feet in thickness. There are, perhaps, 10 or 15 coal-seams exposed along the entire length of the outcrop, with a dip of 5 to 10 degrees to the south-south-east with undulations, in a thickness of perhaps 500 feet of exposed strata.

The village of Sushitna lies 25 miles above the mouth of the

* *Twentieth Annual Report of the United States Geological Survey*, 1898-1899, part vii., page 21.

river, and contains a fur-store, 14 white men and about 40 Indians. There are no signs of coal at the village.

*Tyonek.*—The area of the Tyonek field has not been investigated, but it is inferred that it extends for several miles inland, and from a point 7 or 8 miles west of Tyonek along the coast as far northward at least as Theodore river. From a point, 2 miles west of Tyonek, to one about 6 miles west, there is a continuous outcrop of the Kenai formation (sandstones, shales and coal-seams) along the beach-bluffs. The strata dip south-eastward from 35 to 60 degrees (the amount varying locally), exposing about 36 seams. It is possible that some of the seams are repetitions by faulting, though no actual evidence to this effect was found. The seams vary in thickness from 1 foot to 15 feet, and there are several varying from 4 to 6 feet in thickness.

This coal-field probably covers a large area, the general strike being north-north-east, which would carry the strata to a point about 10 miles up the Chulitna, where coal is reported to exist in seams equal in size and number to those found on the beach.

Mr. G. H. Eldridge records a number of analyses of these seams, as shown in Table I.

TABLE I.—ANALYSES OF COAL FROM THE TYONEK COAL-FIELD.

| No. of Sample. | 1. | 2. | 3. | 4. |
|---|---|---|---|---|
| | Per cent | Per cent. | Per cent. | Per cent. |
| Moisture ... ... | 5·41 | 9·07 | 9·47 | 9·44 |
| Volatile matter ... | 65·13 | 49·41 | 53·53 | 48·75 |
| Fixed carbon ... .. | 27·60 | 30·84 | 31 66 | 33·56 |
| Ash ... | 1·86 | 10·68 | 5·34 | 8·25 |
| Sulphur ... ... | 0·26 | 0·41 | 0·36 | 0·49 |
| Coke ... ... | None. | None. | None. | None. |

NOTES.—1. Portion of a seam seen crossing the beach about 4 miles west of Tyonek (selected wood-coal). 2. Sample taken from the best portions of three or four different seams found along the beach, 3½ to 3¾ miles westward of Tyonek (coal). 3. Portions of a seam seen crossing the beach 2½ miles westward of Tyonek, the first seam west of the village; the sample represents a bed of coal, 1½ feet thick, occurring in a seam 12 feet thick. 4. Portions of a seam found 6 miles west of Tyonek, taken from a stock-pile at Tyonek, for use on the small steamer "Perry," plying on the waters of Cook Inlet.*

* *Twentieth Annual Report of the United States Geological Survey*, 1898-1899, part vii., page 23.

The United States Government have located a summer-station at Tyonek, during the past two years, having been constructing a trail up the Yukon river to admit of access of explorers into the interior of the country. The land immediately behind Tyonek is marshy, with no fallen timber, and the winter population consists of a few whites and 76 Indians.

*Beluga River.*—Coal is reported to exist about 30 miles up the Beluga river, nearly in line with the Chulitna and Tyonek areas. This would indicate an outcrop on the strike, beneath the superficial deposits of silt and gravel, approximately 30 miles in length, with a width (as shown at the beach) of 4 miles.

On the beach, 20 miles below the mouth of the Beluga river, fine gold is found, although not occurring in paying quantities.

In the opinion of the writer, this area will not be of much value, as there is no available harbour; and, on account of shoals and shallow water, steamers are compelled to lie about ½ mile off shore, and discharge or load by means of rafts. The ice freezes much stronger along the shores of Cook Inlet than it does farther south, and it is probable that a pier or wharf would not withstand the winter's storms, and the break-up of the ice in the spring.

II.—Kachemak Bay Coal-field (Fig. 3, Plate XVI.).

On the accompanying section (Fig. 9, Plate XVII.) of the bluffs on the northern shore of Kachemak Bay, no coal-seam is seen in the neighbourhood of Anchor Point—the lowest coal-cropping rising from the sea, is found 3 miles east of Anchor Point; although lower croppings west of this one are seen in the sea at extreme low-tide. The bluffs at Anchor Point are only about 20 feet high, although the ground rises to a height of 200 feet in about 600 feet inland, behind which it dips inland for miles, over a plateau densely timbered with spruce. This range of hills trends eastward more or less parallel and close along side the bay, as far as Bluff Point, forming the bluffs at this headland, at least 300 feet high, thence it takes an inward turn, leaving a strip of peaty, miry, thickly timbered ground off to the sea, which gains a width of over 1 mile in extent at or near the head of Homer Spit. The top of this first range of hills here has an elevation of 1,000 feet, and continuing in the same course gains a height of 1,800 feet above Eastland canyon, whence it runs

inland towards Lake Tustumena. Parallel and behind this first range of hills run a second and a third range, each gaining a slightly higher elevation, and forming a rolling, thickly-timbered country towards the interior.

At Anchor Point, the measures contain two beds of gold-bearing gravel, one cropping in the bluffs just above high-water mark, and the other a few feet below it. These deposits are no doubt due to glacial action, and it is reported that Capt. Cook mentions their existence hereabouts in his memoir on his discovery of Cook Inlet in 1749. Seemingly, however, it is a purely local and limited deposit. In 1897, a sum of £30,000 was spent in purchasing these claims and erecting hydraulic machinery, which, however, was only run for a portion of a single day and then shut down. Only a few pounds of fine gold in all has been taken out hereabouts by prospectors at odd times, at the most about £1 a day, the gold being too fine to catch by the usual methods and little or no water being available.

About midway between Anchor Point and the head of Kachemak Bay is situated the only available harbour on this section of the coast, namely, Homer, a settlement at the extremity of a long, narrow and practically level strip of land, 4 to 5 miles long and from 2,000 feet up to 2 miles broad at its head, composed of sand, gravel and coal, and presumably in the first instance caused by a slide, but which is gradually growing wider year by year through the action of tide and drift. One branch of the Japanese current sweeps close past the end of this Spit, circulating round near this point, and losing itself in depth. By building out a wharf from the end of this Spit for a distance of 330 feet, a depth of 45 feet of water was obtained—a sufficient draught for almost any sized vessel likely to be met with in these waters. Elsewhere along the coast, and especially south-west towards the mouth of the bay, the offshore for some distance out is shallow and exposed to the full force of the swell (and ice in winter) from the Pacific Ocean, rendering it difficult if not impossible for either a pier to be built out and stand, or else an undertaking operated where barges could be loaded, and then taken out alongside vessels lying in the bay. Between Homer Cape and the head of the bay, the offshore is also shoaly, but more of the nature of mud-flats, and this probably accounts for all the prospecting on these coal-outcrops having up to the present time only been conducted along this section of the

coast, the only one described by Dr. Dall in his report. The superior quality of the croppings westward of and lying between Anchor Point and Homer Spit has been ignored, no doubt, partly for this reason, and also, probably, owing to the necessity of a light railway being constructed along and from the mainland to the extremity of the cape, before any coal from this section of the coast could be put on to the markets.

## III.—Climate.

The climate of the coast and of the interior of Alaska are unlike in many respects, the difference being intensified by exceptional physical conditions, as perhaps in few other countries. The natural contrast between land and sea is tremendously increased by the Japanese current of warm water, which impinges on the coast of British Columbia: one branch flowing northward towards Sitka, and thence westward to the Kadiak and Shumagin islands. Consequently the fringe of islands that separates the mainland from the Pacific Ocean, from Dixon Sound northward, and also a strip of the mainland, for possibly 20 miles back from the sea, following the sweep of the coast, as it curves to the north-westward, to the western extremity of Alaska, form a distinct climatic division which may be called "temperate Alaska." North of the Aleutian Islands the coastal climate becomes more rigorous in winter, but in summer the difference is much less marked.

The writer was unable to record the reading of the thermometer for a whole year, but Table II. records a summary of the temperatures during his sojourn at the mine on the mainland near the head of Homer Spit.

On comparing these observations with a register kept at the end of the Spit, the writer found that the latter averaged 2° Fahr. less all the winter, no doubt owing to the cold winds always prevalent, coming from a glacier on the opposite side of the bay. He also noted that at Anchor Point the temperature averaged 10 degrees lower than at the mine he was opening, and this was probably owing to the effect of the winds from the Pacific Ocean.

Although during the winter, a considerable thickness of ice formed along the shores of the bay, yet the channel was always open, and the steamers carrying the mails were invariably able to get alongside the company's dock at the end of Homer Spit, on their arrival once a month.

Considerable fear was felt that the dock would be carried away by ice, but the salt-water ice was of a very much softer nature than the freshwater ice, and when the largest ice-fields were in the bay during any part of the winter, with an outrunning tide thrusting the ice against the dock, a person could press back the largest chunks with a pike-pole, from which it appeared that there was very little pressure. The piles of this dock were put in with a pile-driver (the piles being spaced 8 feet apart all round the dock, and a boom-chain was slung around the end, with its ends fastened to the shore), but the Coal Camp dock erected farther up the bay, 6 years previously (the piles of which were only put in by a shovel), and quite as exposed to the flow of ice and ice gathering under it, had stood up to the present time, without either having been lifted or moved by ice. The danger of demolition through ice, as often occurs on the big freshwater lakes of Canada, is when the solid blue ice, sometimes floating in cakes 20 miles long, and carried by the wind, which may have remained in one quarter for some days, begins to move, and then it sweeps everything before it.

TABLE II.--TEMPERATURE OBSERVATIONS.

| Week ending. | Average readings taken at 6 a.m. | Average readings taken at midday. | Highest reading. | Lowest reading. | Week ending. | Average readings taken at 6 a.m. | Average readings taken at midday. | Highest reading. | Lowest reading. |
|---|---|---|---|---|---|---|---|---|---|
| 1899. | Dgs. Fh. | Dgs. Fh. | Dgs. Fh. | Dgs. Fh. | 1899. | Dgs. Fh. | Dgs. Fh. | Dgs. Fh. | Dgs. |
| June 10 | 47½ | 55 | 59 | 42½ | Dec. 30 | 6 | ... | 10 | 2 |
| ,, 17 | 55½ | 58 | 64 | 48 | 1900. | | | | |
| ,, 24 | 54⅗ | 61 | 68 | 51 | Jan. 6 | 20½ | ... | 29 | 6 |
| July 1 | 55 | 58½ | 67 | 50 | ,, 13 | 24½ | ... | 34 | 12 |
| ,, 8 | 68¾ | 66 | 74 | 67 | ,, 20 | 1½ | ... | 8 | -5 |
| ,, 15 | 56½ | 57½ | 63 | 54 | ,, 27 | 10½ | ... | 30 | 2 |
| ,, 22 | 55 | 59 | 59 | 52 | Feb. 3 | 29 | 32 | 42 | 22 |
| ,, 29 | 57½ | ... | 62 | 53 | ,, 10 | 28½ | 42¾ | 46 | 22 |
| Aug. 5 | 56 | .. | 62 | 54 | ,, 17 | 23 | ... | ... | 18 |
| ,, 12 | 55 | 57 | 57 | 54 | ,, 24 | 22½ | ... | 30 | 12 |
| ,, 19 | ... | 58 | 62 | ... | Mar. 3 | 23 | 44 | 45 | 18 |
| Dec. 2 | 34½ | | 46 | 30 | ,, 10 | 20½ | 45½ | 47 | 4 |
| ,, 9 | 28½ | ... | 43 | 20 | ,, 17 | 34½ | ... | 44 | 15 |
| ,, 16 | 21 | ... | 40 | 20 | ... | .. | ... | ... | ... |
| ,, 23* | 10½ | ... | 24 | -2 | May 5 | 42 | 50 | ... | ... |

* The first snow fell on December 23rd, 1899, attaining a depth of 2½ feet.

The usual yearly climate may be classified into two well-marked periods, a long winter, extending from October until well into

May, and five months of summer. The winter is by far the best season, as there are long periods of beautifully clear days, which are welcomed in spite of the usually accompanying intense cold. The summer is rendered very disagreeable by a large number of cold, misty rains, and owing to the swampy, miry nature of the soil, the warm weather brings swarms of mosquitoes, accompanied by an equally vindictive ally in the shape of a small, poisonous black fly, the two holding high carnival of human torture from the first growth of spring vegetation in May, until it is withered by the frosts late in September.

## IV.—Agriculture.

Agriculturally, the bulk of the land is of little value, the surface, for the most part, being covered with about 1 foot of moss and dense forests of spruce, not more than 10 to 12 inches in diameter. The roots of the trees, owing to the moss, have little hold in the ground, and consequently with the high winds of the spring and fall of the year, they are blown down. This has been going on maybe for centuries, and other trees springing up in their places render the interior of the country most difficult to prospect, the logs lying in patches all around, heaped up one on the top of another.

Near the head of Homer Spit, and also at the foothills, are small tracts of vacant ground requiring very little clearance, and covered with a kind of long Hungarian grass growing from 5 to 7 feet high, and this, if cut and properly dried, could be turned into nourishing hay. There is no doubt that these small tracts could be turned to profitable account if tilled.

Unless a series of ditches are run, difficulty will always be experienced in keeping transportation-trails open, especially in the spring, unless they are corduroyed from end to end; and when the frost begins to come out of the ground, owing to the swampy nature of the country, they become almost impassable.

## V.—Geology.

Table III. contains an approximate section of the coal-bearing measures exposed on the edge of the Bluff on the northern shore of, and between the head and the mouth of Kachemak Bay and Anchor Point.

TABLE III.—APPROXIMATE SECTION (FIG. 9, PLATE XVII.) OF COAL-BEARING MEASURES EXPOSED ON THE BLUFFS ON THE NORTHERN SHORE OF KACHEMAK BAY.

| Location. | No. | Description of Strata. | Thickness of Coal-seams. Ft. | In. | Thickness of Intervening Strata. Ft. |
|---|---|---|---|---|---|
| Between mouth of Sheep Creek and Fox River | 1 | Strata covered with grass, etc. | | | 467 |
| Between Fox River and Eastland Canyon | 2 | Strata with thin coal-seams | | | 165 |
| | 3 | Coal-seam ... ... ... | 2 | 6 | |
| | 4 | Strata ... ... ... | | | 3 |
| | 5 | Coal-seam ... ... ... | 3 | 0 | |
| | 6 | Strata ... ... ... | | | 12 |
| | 7 | Coal-seam ... ... ... | 6 | 0 | |
| | 8 | Strata ... ... ... | | | 94 |
| Between Eastland and Cottonwood Canyons | 9 | Coal-seam, with 28 inches of coal | 6 | 0 | |
| | 10 | Strata ... ... ... | | | 23 |
| | 11 | Coal-seam ... ... ... | 2 | 6 | |
| | 12 | Strata ... ... ... | | | 25 |
| | 13 | Coal-seam ... ... ... | 2 | 0 | |
| | 14 | Strata .. ... ... | | | 12 |
| Between Cottonwood and McNiel Canyons | 15 | Strata with thin coal-seams varying from 6 inches to 2 feet | | | 130 |
| | 16 | Coal-seam ... ... ... | 4 | 0 | |
| | 17 | Strata ... ... ... | | | 35 |
| | 18 | Curtis Coal-seam, coal ... | 7 | 0 | |
| | 19 | Strata ... ... ... | | | 26 |
| Between McNiel and Fritz Canyons | 20 | Strata ... ... ... | | | 72 |
| | 21 | Coal-seam ... ... ... | 2 | 6 | |
| | 22 | Strata ... ... ... | | | 4 |
| | 23 | Coal-seam ... ... .. | 2 | 0 | |
| | 24 | Strata ... ... ... | | | 10 |
| | 25 | Coal-seam ... ... ... | 2 | 0 | |
| | 26 | Strata ... ... ... | | | 8 |
| | 27 | Coal-seam ... ... ... | 3 | 0 | |
| | 28 | Strata ... ... ... | | | 145 |
| | 29 | Coal-seam ... ... ... | 2 | 0 | |
| | 30 | Strata ... ... ... | | | 45 |
| | 31 | Coal-seam ... ... ... | 4 | 0 | |
| Between Fritz Canyon and Cooper Creek at head of Homer Spit | 32 | Strata ... ... ... | | | 557 |
| | 33 | Coal-seam ... ... ... | 2 | 6 | |
| | 34 | Strata ... ... ... | | | 3 |
| | 35 | Coal-seam ... .. ... | 3 | 0 | |
| | 36 | Strata ... ... ... | | | 3 |
| | 37 | Coal-seam, inferior ... ... | 4 | 0 | |
| | 38 | Strata .. ... ... | | | 23 |
| | 39 | Bradley Coal-seam, coal & dirt | 8 | 0* | |
| | 40 | Strata ... ... ... | | | 320 |
| Between head of Homer Spit and Bluff Point | 41 | Coal-seam, with dirt-parting | 4 | 3† | |
| | 42 | Sandstone ... ... ... | | | 20 |
| | 43 | Coal-seam ... .. ... | 2 | 0 | |
| | 44 | Fire-clay ... ... ... | | | 8 |
| | 45 | Coal-seam ... ... ... | 1 | 4 | |
| | 46 | Sandstone ... ... ... | | | 15 |

* Sections have been measured in Cooper Canyon as follows:—

| WEST SIDE. | Ft. | In. | EAST SIDE. | Ft. | In. |
|---|---|---|---|---|---|
| Coal thin .. .. .. .. .. | — | | | | |
| Strata .. .. .. .. .. .. | — | | | | |
| Coal, thin .. .. .. .. .. | — | | | | |
| Strata .. .. .. .. .. .. | — | | Soft muck roof .. .. .. .. .. | — | |
| Coal .. .. .. .. .. .. | 0 | 9 | Coal . .. .. .. .. .. | 0 | 9 |
| Dirt . .. .. .. .. .. | 0 | 4 | Dirt .. .. .. .. .. .. | 0 | 4 |
| Coal .. .. .. .. .. .. | 2 | 0 | Coal .. .. .. .. .. .. | 0 | 9 |
| Dirt .. .. .. .. .. .. | 1 | 3 | Dirt .. .. .. .. .. .. | 1 | 3 |
| Coal .. .. .. .. .. .. | 1 | 10 | Coal .. .. .. .. .. .. | 1 | 10 |
| | 6 | 2 | | 4 | 11 |

† Coal, 3 feet; dirt, 3 inches; and coal, 1 foot.

TABLE III.—(*Continued*).

| Location. | No. | Description of Strata. | Thickness of Coal-seams. Ft. | In. | Thickness of Intervening Strata. Ft. |
|---|---|---|---|---|---|
| | 47 | Coal-seam ... ... ... | 2 | 6 | |
| | 48 | Strata ... ... ... | | | 8 |
| | 49 | Coal-seam ... ... ... | 1 | 4 | |
| | 50 | Strata ... ... ... | | | 40 |
| | 51 | Cooper Thick Coal-seam, coal | 7 | 0 | |
| | 52 | Fire-clay ... ... | | | 2 |
| | 53 | Coal-seam ... ... ... | 1 | 0 | |
| | 54 | Strata ... ... ... | | | 12 |
| | 55 | Coal-seam ... ... ... | 1 | 0 | |
| | 56 | Strata ... ... ... | | | 15 |
| | 57 | Coal-seam ... ... ... | 1 | 0 | |
| Between Bluff Point and Antonne Creek | 58 | Strata ... ... ... | | | 82 |
| | 59 | Coal-seam ... ... ... | 3 | 0 | |
| | 60 | Strata ... ... ... | | | 2 |
| | 61 | Coal-seam ... ... ... | 3 | 0 | |
| | 62 | Strata ... ... ... | | | 6 |
| | 63 | Coal-seam ... ... ... | 2 | 0 | |
| | 64 | Strata ... ... ... | | | 6 |
| | 65 | Coal-seam ... ... ... | 1 | 0 | |
| | 66 | Strata ... ... ... | | | 2½ |
| | 67 | Coal-seam ... ... ... | 1 | 0 | |
| | 68 | Strata ... ... ... | | | 27 |
| | 69 | Coal-seam ... ... ... | 2 | 6 | |
| | 70 | Strata ... ... ... | | | 10 |
| | 71 | Coal-seam ... ... ... | 2 | 0 | |
| | 72 | Strata ... ... ... | | | 30 |
| | 73 | Coal-seam ... ... ... | 3 | 6 | |
| | 74 | Strata ... ... ... | | | 30 |
| | 75 | Coal-seam ... ... ... | 5 | 6 | |
| | 76 | Strata ... ... ... | | | 5 |
| | 77 | Coal-seam ... ... ... | 2 | 0 | |
| | 78 | Strata ... ... ... | | | 6 |
| | 79 | Coal-seam ... ... ... | 2 | 0 | |
| | 80 | Strata ... ... ... | | | 10 |
| | 81 | Coal-seam ... ... ... | 4 | 0 | |
| | 82 | Strata ... ... ... | | | 3 |
| | 83 | Coal-seam ... ... ... | 0 | 6 | |
| | 84 | Strata ... ... ... | | | 1 |
| | 85 | Coal-seam ... ... ... | 0 | 2 | |
| | 86 | Strata ... ... ... | | | 3 |
| | 87 | Coal-seam ... ... ... | 0 | 6 | |
| | 88 | Strata ... ... ... | | | 2 |
| | 89 | Coal-seam ... ... ... | 0 | 6 | |
| | 90 | Strata ... ... ... | | | 1 |
| | 91 | Coal-seam ... ... ... | 3 | 0 | |
| | 92 | Strata ... ... ... | | | 5 |
| | 93 | Coal-seam ... ... ... | 1 | 0 | |
| | 94 | Strata ... ... ... | | | 30 |
| | 95 | Coal-seam ... ... ... | 4 | 0 | |
| Between Antonne Creek and Travers Creek | 96 | Strata ... ... ... | | | 20 |
| | 97 | Coal-seam ... ... ... | 1 | 0 | |
| | 98 | Strata ... ... ... | | | 1 |
| | 99 | Coal-seam ... ... ... | 2 | 0 | |
| | 100 | Strata ... ... ... | | | 3 |
| | 101 | Coal-seam ... ... ... | 1 | 0 | |
| | 102 | Strata ... ... ... | | | 92 |
| | 103 | Coal-seam ... ... ... | 1 | 0 | |
| | 104 | Strata ... ... ... | | | 1 |
| | 105 | Coal-seam ... ... ... | 2 | 0 | |
| | 106 | Strata ... ... ... | | | 3 |
| | 107 | Coal-seam ... ... ... | 4 | 0 | |
| | | | 139 | 7 | 2,683½ |

TABLE IV.—SECTION IN THE HILLS BEHIND TRAVERS CREEK.

| | Feet. |
|---|---|
| Peaty clay ... ... .. ... ... | 2 to 4 |
| Porphyry gravel ... ... ... ... ... | 3 to 4 |
| Intermediate sandstones and blue clay, with hard sandstone-boulders ... ... ... . | 150 |
| Gold-bearing gravel ... ... ... | 1 to 3 and 10 |
| Hard tough blue clay ... ... ... ... ... | 27 |
| Grey sandstone ... ... ... ... ... ... | 2 |
| Good coal ... ... ... ... ... ... | 4 |
| | 201 |

TABLE V.—SECTION OF THE BLUFFS IN FRONT OF ANCHOR POINT.

| | Feet. |
|---|---|
| Peaty soil ... ... ... ... ... | 4 to 6 |
| Glacial mud ... ... ... ... .. | 4 to 6 |
| Gold-bearing gravel ... ... ... ... | 1 to 2 |
| Glacial mud and clay ... ... ... ... ... | 2 |
| Level of high-water mark ... ... ... ... | — |
| Gold-bearing gravel* ... ... ... ... | 1 to 2 |
| Porphyry gravel mixed with iron-ore ... ... | ? |

* The gold-bearing gravel is a mixture of ruby and black sand, and magnetic iron-ore.

In driving a slope and passing through solid measures, the writer proved the dip of the measures to be north 21½ degrees east at the rate of 2·61 inches to the yard or in the direction towards the interior. Dr. Dall erroneously gives it as being 15 degrees north at 9·64 inches per yard. As seen along the Bluff, the coal-seams are running more or less in rolls and at the outcrops it is impossible to form any correct idea of the dip, the sea having undermined the coal-seams more or less all along the Bluff, by washing away the softer clays underlying them; and this, together with the overlying strata, has caused them to settle unconformably.

These coal-seams may be classed into two definite groups:—The coals forming the lower portion of the Bradley seam and those lying below it are of a decided *glanzkohle* character throughout, showing little or no cleavage. Fig. 9 (Plate XVII.) shows the outcrop in the edge of the bluffs to the west of the head of Homer Spit and also at Bluff Point. They have a more compact texture, and are of a superior appearance and higher specific gravity. In the other group or upper seams, the coal has a decided cleavage and retains many of the characteristics of the woody nature of its composition, breaking up into elongated pieces

like chips rather than into cubical blocks as does *glanzkohle* or glance coal. Being (according to the classification of Prof. Zincken) what is called earthy or fibrous brown coal, it gives off less heat when burning than glance coal, owing to the dirt fibres in it making both clinker and ash. Glance coal is often mistaken by prospectors for anthracite, but it has a lower specific gravity, and is of a wholly different structure.

The coal-seams enumerated by Dr. Dall as having been prospected and analysed are as follows:—Travelling northeastward, about 3 miles past the head of Homer Spit, the first location prospected is that made by Mr. J. A. Bradley on a seam comprising several beds of coal, lying close together and aggregating a thickness of about 7 feet, and separated by thin layers of leaf-bearing shale. It is one of the lowest coals and the best of any found on this side of Homer Spit—the lowest portion of this seam (about 18 inches of clear coal) is the thickest and best. The Alaska Coal Company drove a tunnel in 1888, and the following is an analysis of a sample taken from the tunnel:—

| | Per cent. |
|---|---|
| Moisture ... ... ... ... ... | 12·64 |
| Volatile matter ... ... ... ... | 43·36 |
| Coke ... ... ... ... ... .. | 37·14 |
| Ash .. ... .. ... ... ... | 6·86 |

This portion of the seam has a brilliant fracture, breaking into cubical fragments when dry with duller streaks; there is no visible pyrite, and when burnt it leaves a fine, grey ash without clinkers. The coke is dull and non-coherent. The percentage of sulphur is 0·49, and of phosphorus pentoxide 0·021. The ash contains 12·88 per cent. of lime, and 5·34 per cent. of ferric oxide.

An analysis, given in the prospectus of the Alaska Coal Company, made by Mr. Thomas Price, of a sample of coal from their property probably taken from this seam, showed:—

| | Per cent. |
|---|---|
| Moisture ... ... ... ... ... | 8·55 |
| Volatile matter ... ... ... ... | 32·50 |
| Coke ... ... ... ... ... | 56·00 |
| Ash ... ... ... ... ... ... | 2·95 |

The writer doubts the correctness of this analysis, as another made by Dr. Newberry of the School of Mines, Columbia College, New York, is as follows:—

| | Per cent. |
|---|---|
| Moisture ... ... ... ... ... | 1·25 |
| Volatile matter ... ... ... ... | 39·84 |
| Coke ... ... ... ... ... ... | 49·89 |
| Ash ... ... ... ... ... ... | 7·82 |
| Sulphur ... ... ... ... .. | 1·20 |

This specimen had been a long time in hand before it was analysed, and had probably lost part of its original moisture. It was probably obtained from Port Graham, that is, from a much lower seam than the Bradley seam, or any existing so far to the north-eastward.

The next location where any work has been effected is at McNiel canyon, where in 1891 Lieut. R. P. Schwerin, of the United States Navy, worked 200 tons, which was taken to San Francisco and submitted to a series of tests; but although he found the coal broke into chip-like fragments rather rapidly after exposure to a dry atmosphere, he states that it gave very satisfactory results under stationary boilers. A test, made by the Southern Pacific Railway Company in California on their locomotives, proved it totally unfit for use as a steam-coal owing to a tendency for sparking, which under forced draught was very pronounced, in spite of the use of fine netting over the chimney-stacks.

The next location is at the Cottonwood canyon, but here very little exploration-work has been done, and no analyses have been made of the coal.

At Eastland canyon, exploration-work was prosecuted at a cost of £18,000 on a seam aggregating a thickness of 6 feet, but only containing 2 feet 4 inches of good, clean coal, above which lie alternating thicknesses of coal and clay or bone. Dr. Dall gives the following analyses in his report:—

| Sample. | No. 1. Per cent. | No. 2 Per cent. | No. 3. Per cent. |
|---|---|---|---|
| Moisture ... ... | 11·72 | 10·35 | 11·59 |
| Volatile matter ... | 46·50 | 52·22 | 50·70 |
| Coke ... ... | 34·64 | 34·58 | 30·84 |
| Ash ... ... | 7·14 | 2·85 | 6·87 |

In No. 1 sample, the coal was dull, charcoal black, with an apparently fibrous structure, breaking into elongated splinters and chips, and giving when scratched a dark reddish-brown streak. The coke is dull and non-coherent, the ash yellowish. In the

whole coal, the percentage of sulphur is 0·40, and of phosphorus pentoxide 0·69. The ash contains 27·37 per cent. of lime, and 6·28 per cent. of ferric oxide.

No. 2 specimen was taken from a mass which had been exposed to the weather. The coke is dull and very slightly coherent. The appearance of the coal resembled No. 1 sample, and it contained 0·17 per cent. of sulphur.

The coke of No. 3 sample is dull and non-coherent. The percentage of sulphur in the whole coal is 0·22, and of phosphorus pentoxide 0·10. The ash contains 30·86 per cent. of lime, and 5·17 per cent. of ferric oxide.

We may return southwestward, to about 2 miles west of the head of Homer Spit, where the writer started drifting in the Cooper Thick coal-seam. This seam averages from 7 to 9 feet in thickness, and seemingly comprises two different beds with a small clay-parting between; the lower coal, of a superior quality, is a *glanzkohle*, whilst the upper bed is more of an earthy or fibrous nature, showing a decided cleavage running about north 60 degrees west.

This lignite weighs about 75 pounds to the cubic foot, and appears to be of better quality than any seam previously opened up in the field. The writer has not seen analyses of a large sample taken out from the edge of the bluffs and sent down by him to Seattle, but he was told that it did not run so high in fixed carbon as that analysed by Prof. Newberry, presumably from the neighbourhood of Port Graham, and hereinbefore described; although it proved superior to any made from the upper coal-seam and recorded in Dr. Dall's report.

The coal is adapted for domestic purposes, giving a hot, bright fire with little smoke or soot; it is clinkerless, and leaves but little ash of a fine, soft nature.

It is doubtful whether this coal will gain a market for locomotive purposes, as (similarly to the sample tested by the Southern Pacific Railway Company of coal from an upper seam) it breaks up into small flakes whilst burning, which are emitted up the flue. Whilst driving piles for the wharf, the engineer (who stated he had had 15 years' experience with west coast coals) declared that it was better than any previous coal he had used on the Pacific coast.

This coal is of little value for blacksmith's purposes, it being

found impossible to make a weld with it (coal having to be sent from Seattle for this purpose), although it answered all right in sharpening picks, etc. It has no coking qualities whatever. It is a hot coal, but it remains to be seen how it answers for marine purposes under forced draught, owing to its before-mentioned tendency to sparking.

In a short test made by the writer, in the condenser erected at the end of Homer Spit for evaporating the sea-water into fresh, it was found that 1 pound of this coal evaporated 7 pounds of salt water under generally unfavourable conditions, and comparing this test with that of an upper coal-seam given by Prof. Schwerin, who only evaporated 4·46 pounds of water per pound of fuel, it will be seen that it has superior qualities.

Before leaving the district, the writer gathered samples from the majority of the workable coal-seams, and also samples from the other various fields of the Pacific West Coast, all of which were exhibited to the members. One of the samples taken from the best coal-seam that he found cropping out in any part of the Kachemak Bay coal-field, namely, the one (Fig. 9, Plate XVII.) dipping into the sea nearest to any shown thereon, but east of Anchor Point, was analysed by the courtesy of the provincial mineralogist, Mr. William Fleet Robertson, as follows: —

| | Per cent. |
|---|---|
| Moisture ... ... ... ... ... | 11·4 |
| Volatile combustible matter ... ... | 39·5 |
| Fixed carbon ... ... ... ... | 44·0 |
| Ash ... ... ... .. .. ... | 5·1 |

This analysis does not speak very highly for the future commercial prospects of any portion of the coal-field.

A plentiful supply of spruce timber is available for mining purposes, but it is not very strong, and has only about one third the life of Washington fir.

In a summary attached to his report on Alaskan coal-seams, Dr. Dall stated that as far as composition went the lignites of Amalik harbour, Chignik river, and the McCluskey seam of Kootznahoo are all of a better quality than the best of the Kachemak Bay lignites. Yet, owing to the undisturbed condition of the strata as a whole, the thickness, position and extent of the seams, the accessibility of wood for timbering and its cost, and also to the fact that

there is an excellent harbour open at all seasons of the year, he thinks, if there is a commercial future for any of the Alaskan coal-seams, owing to situation, etc., those of Kachemak Bay might find a market in California, if mined in such an economical way as to be sold for a price equivalent to its commercial efficiency with competitive fuels. The McCluskey seam at Kootznahoo is too little developed to allow of any estimate of its extent, and the Amalik harbour seam is too thin to admit of profitable working, notwithstanding the high quality of the coal.

After so many tests of these coals (as recorded by Dr. Dall), taken from different prospects and outcrops, but all upper beds, the fact that all these prospects have been abandoned does not speak very highly for this coal-field.

## VI.—Labour-supply and Wages.

The question of labour-supply is also a serious difficulty to contend against in the development of an outlandish property, away from civilization, and more especially if it is *en route* to any gold-mining rush, as it is impossible for a coal-mining company to pay the same rate of wages as in a metal camp.

In 1894, men were shipped from San Francisco, the company paying their passage and then 4s. 2d. (1 dollar) per ton for mining the coal and tramming it to the nearest passbye, and charging them 20s. 10d. (5 dollars) per week for board. The miners' wages averaged 16s. 8d. to 20s. 10d. (4 to 5 dollars) per day.

In 1899, men were engaged on a 6 months' agreement and shipped from Seattle and furnished with free passage and 8s. 4d. (2 dollars) per day remuneration until arrival at their destination, and then 1s. (25 cents) per hour with board (in the case of miners 10s. 5d. or 2½ dollars per day of 8 hours, with board), but owing to superior attractions elsewhere during the summer months, constant difficulty was experienced in keeping the full complement of men. No dependence could be placed on them, several having taken their departure by the first steamer calling in the spring, preferring to forfeit their passage-money back to civilization rather than relinquish the possible chance of making a better stake elsewhere.

The only available local labour that can be obtained is from the Indian villages of Soldovia, English Bay, and Nielchic, these Indians being as a rule good woodsmen but uncertain workers.

A clearance can usually be effected through them at about a third the rate that white labour would demand; the general standard out west for clearing through thick ground with white labour is £20 (100 dollars) per acre, but owing to the uncertainty of working long at a stretch, the Indians are of little use as miners.

One solution of the labour difficulty would be to ship into the country a batch of Finns or other cheap labour, thus establishing a small colony. Owing to the nature of the soil, and the mildness of the winter (through the action of the Japanese current, the thermometer, during the winter, rarely falling much below zero), this would not be such a serious venture as at first sight appears.

### VII.—Amalik Harbour, etc., Coal-fields.

*Amalik Harbour Coal-field.*—The coal-measures of the Amalik harbour district comprise a thickness of 250 feet or more of sandstones, dipping about north 30 degrees east; and low down in the series are strata of stream-bedded, sharp gravel, in layers about 5 feet thick, with three seams of impure coal each about 18 inches thick. There is about 4 inches of pure, glossy coal having a bituminous aspect, and unlike other Alaskan coals, it soils the fingers when handled, and is said to be of use in a blacksmith's forge. These beds are, however, broken off to the east by a granitic dyke, weathering reddish, and were probably once covered by a more recent bed of basalt, which forms the mass of the adjacent hills. On analysis, this coal afforded the following results:—

| | Per cent. |
|---|---|
| Moisture ... ... ... .. .. | 1·62 |
| Volatile matter ... .. ... .. | 36·56 |
| Coke .. ... ... .. ... ... | 52·92 |
| Ash ... ... ... ... .. ... | 8·90 |

The ash is yellowish, the coke rather brilliant and coherent, and the percentage of sulphur is 0·75. This is superior to any other analyses from other Alaskan districts, but the thinness of the seam prohibits profitable working; although this vicinity is almost unknown, and further explorations might develop more abundant deposits.

*Chignik River Coal-field.*—At Chignik river, at the upper part of the lagoon comprising Chignik Bay, which is nearly dry at

low tide, is a thin seam of coal, found on one of the banks of the river a few miles from the sea. This seam averages 16 inches in thickness, and contains a streak of sandstone 1 inch thick, above which come 11 inches of hard sandstone and 6 inches of coal; and then about 6 feet higher is another seam 6 or 8 inches thick, closely adhering to a firm sandstone-roof. The beds are very regular with a few small slips, and dip north 25 degrees east, the strike running from north 15 to 20 degrees west. The coal is solid, clean and bright, with no visible pyrite or lime, and has been traced inland for more than ½ mile. The following is an analysis of this coal:—

| | Per cent. |
|---|---|
| Moisture ... .. ... ... ... | 1·89 |
| Volatile matter ... ... .. ... | 41·47 |
| Coke ... ... ... ... ... ... | 48·46 |
| Ash ... ... ... .. ... ... | 8·18 |

The coke is brilliant and cohesive. The sulphur in the coal is 1·71 per cent. Experiments have shewn that 118 pounds of this coal equalled 100 pounds of Wellington (British Columbia) coal. The ash is granular and reddish-grey in colour. The coal gives off very little smoke, and is a satisfactory steaming coal. Three men were employed working the seam during the summer, who produced 2½ tons per day at a cost of 12s. 6d. (3 dollars) per ton. In winter, 2 men are employed, who are paid 25 cents per hour worked.

There are a few other districts on the south-western coast of Alaska where small patches of Tertiary beds containing seams of lignite occur, and analyses of the coals are embodied in Table VI.

TABLE VI.—ANALYSES OF ALASKA LIGNITES.

| Locality. | Moisture. | Volatile Matter. | Fixed Carbon. | Ash. | Sulphur. |
|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| Kootznahoo: McCluskey coal-seam | 2·44 | 44·75 | 47·93 | 4·88 | 0·67 |
| ,, Sepphagen ,, | 1·66 | 35·40 | 31·80 | 31·14 | 0·32 |
| ,, Sullivan ,, | 0·82 | 21·86 | 35·52 | 41·80 | 0·51 |
| ,, Mitchell ,, | 2·37 | 31·73 | 30·89 | 35·01 | 0·47 |
| ,, De Groff ,, | 2·57 | 55·44 | 29·75 | 12·24 | 0·89 |
| Kadiak: Red River ... ... ... | 12·31 | 51·48 | 33·80 | 2·41 | 0·17 |
| Unga: Upper coal-seam ... ... | 11·26 | 40·51 | 41·24 | 6·99 | 2·17 |
| ,, Lower ,, ... ... | 10·58 | 66·21 | 15·26 | 7·95 | 0·56 |
| Herendeen Bay ... ... ... | 3·43 | 39·00 | 47·40 | 10·17 | 0·44 |

With the exception of the lignites from Amalik harbour, Chignik river and the McCluskey seam at Kootznahoo, the coals (taking the situation and other conditions into account) are practically more worthless than the lignites of Kachemak Bay, and too thin for profitable working. All these districts were examined by Dr. W. H. Dall and party, and are mentioned in his report.

### VIII.—Chilcat or Kiak Coal-field, Alaska.

During the writer's return trip from Alaska, he learned that bituminous coal had been discovered in several creeks of the Chilcat river, about 14 miles from its mouth, 20 miles from Catalla harbour and 8 or 9 miles from Lake Chilcat. This coal-field seems to belong to the Miocene period, and is of older date than the lignites of Cook Inlet, although by some authorities the difference between this coal and that of Cook Inlet is ascribed to the effects of the folding, and of the large masses of igneous rock in the mountain, which have so altered this coal and the accompanying strata as to increase materially its commercial value as fuel (Figs. 1 and 4, Plate XVI.).

This field is not mentioned in Dr. Dall's report, but the writer was informed by Mr. Schrader (of the United States Geological Survey) that members of his party intended working back to this section of country last summer, and their report would probably be published shortly.

Mr. J. E. Spurr* gives the following particulars of this field, obtained from Mr. F. H. Shepherd, of Nanaimo, British Columbia. Two fields have been investigated. The upper one, adjoining the shores of Controller Bay, reaches from Cape Martin to Chilkat village and comprises metamorphosed Tertiary rocks, containing no marine fossils, but abundant plant-remains, which, however, have been spoiled by folding. The strike everywhere for 20 miles is north 40 degrees east, and the dip 50 to 60 degrees north-west. Inland, nearer the mountain, the rocks seemingly become silicified and more resistant, boulders of crystalline rocks brought down from the mountains consisting of pieces of granite and metamorphosed quartzite with slaty rocks. There are no dykes. There appears to be several coal-seams varying from 10 to 27 feet in thickness. The coal possesses a bright, black lustre, conchoidal

* "Reconnaissance in South-western Alaska in 1898," *Twentieth Annual Report of the United States Geological Survey*, part vii., page 263.

fracture, and has all the characteristics of semi-anthracite, with the exception of hardness and specific gravity. Analyses of these coals are contained in Table VII.

TABLE VII.—ANALYSES OF CHILCAT COAL.

| | No. 1, from neighbourhood of Controller Bay. | No. 2, from neighbourhood of Icy Bay. | No 3. | No. 4. |
|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. |
| Moisture ... | 0·75 | 0·78 | 0·83 | 1·00 |
| Fixed carbon ... | 82·40 | 80·30 | 87·57 | 81·10 |
| Volatile matter | 13·25 | 13·22 | 7·18 | 14·30 |
| Ash ... ... | 3·60 | 5·70 | 4·42 | 3·60 |
| Sulphur ... ... | 0·69 | 2·90 | ... | ... |

Nos. 1 and 2 specimens were taken from outcrops at opposite ends of the coal-field, and show the uniform nature of the coal; the third specimen was analysed by Mr. William H. Fuller, Fairhaven, Washington, in February, 1898; and the fourth analysis was made for the writer by Mr. W. F. Robertson, provincial mineralogist, Victoria, British Columbia, from specimens obtained during the writer's return voyage from Alaska.

In the upper field, but nearer the coast, the strata comprise a thick series of black shales, with few plant-remains and shell-casts, and yielding oil-springs. This series presumably is several thousand feet thick, as also are the supposed Kenai measures.

Before these coals could be put on to the market, a railway about 8 miles in length must be built to the banks of Lake Chilcat, where they could be easily loaded on to barges and towed down to Catalla harbour, a distance of about 15 miles; or else a railway about 20 miles long could be constructed from the outcrops down to the latter place, the gradient of which would only be slight. The main difficulty will be encountered in making a good harbour at Catalla, owing to a long reef of rocks extending across the mouth of the harbour; but the writer was informed that the quantity and quality of these coals would justify the removal of this ledge of rocks, thus making a safe and suitable harbour.

In the lower coal-field of this district, which lies north-west of Icy Bay, the Kenai series does not appear, and only oil is found. These oil-springs are found oozing out along the shores of Catalla

Bay, and also to a distance of 15 miles inland, yielding a superior quality of petroleum. The structure here is a general anticline parallel to the coast, and to the main mountain-range, which, however, is well back of the fold. From Cape Yaktag, a point immediately west of Icy Cape, fossils were collected by Mr. Shepherd from sandstones, thinly bedded limestones and shales, from a point on the mountains 1,000 to 2,000 feet high. Similar fossils were found on the coast as float, and the collection was submitted to Dr. W. H. Dall of the United States National Museum, who reported them as belonging to the Miocene horizon of Empire beds, mostly waterworn pebbles and float specimens. He also adds that the oil or asphalt found in these sandstones was doubtless derived, as elsewhere on the Pacific coast, from underlying Eocene beds.

## IX.—Queen Charlotte Islands (Fig. 6, Plate XVI.).

*Situation and Geological Features.*—The Cretaceous formation is found in the northern portion of Queen Charlotte Island, and anthracite as well as bituminous coal has been known for many years to exist in considerable quantities. These deposits have been the subject of reports by the Geological Survey of Canada in 1872-73 by Mr. Richardson, and again in 1878-79 by the late Dr. G. M. Dawson. According to Dr. Dawson, the thickness of the Cretaceous beds of this island is as follows:—

| | Feet. |
|---|---|
| Upper shales and sandstone ... | 1,500 |
| Coarse conglomerates ... | 2,000 |
| Lower shales, with coal-seams and iron-ore... | 5,000 |
| Agglomerates ... | 3,500 |
| Lower sandstone ... | 1,000 |
| Total ... | 13,000 |

Up to the present time, the island has been but little prospected, owing to the thick underbrush and fallen trees rendering it inaccessible.

The climate is about the same as that of Victoria, British Columbia, or the south of England, owing to the warm waters of the Japanese current sweeping round both sides of the group of islands. The temperature never falls below 0° Fahr. in winter or rises above 90° in summer; it averages about 60° during the summer months.

*Skidegate Inlet District.*—Near Skidegate Inlet on the east coast of Graham Island, the Queen Charlotte Coal-mining Company, Limited, spent a considerable sum of money on the development of their property, but abandoned the enterprise in 1872. According to the best information obtainable, the coal-seam, when opened up, contained from 2 to 3 feet thick of good, clean anthracite, and as the tunnel progressed the seam increased to 6 feet, but further in it decreased until it was 1½ feet thick at the face, and work was then stopped. Dr. Dawson* gives two analyses of anthracite taken from the Cowgitz mine. The first sample was taken from the Hooper Creek tunnel and the second from a 3 feet seam.

| No. of Sample. | (1) | (2) |
| --- | --- | --- |
| | Per cent. | Per cent. |
| Water... | 1·60 | 1·89 |
| Volatile matter | 5·02 | 4·77 |
| Fixed carbon | 83·09 | 85·76 |
| Sulphur | 1·53 | 0·89 |
| Ash | 8·76 | 6·69 |

Dr. Dawson, reviewing the appearance presented by these seams, says it would appear that too great dependence had been placed on their continuity and uniformity without the necessary amount of preliminary exploration to determine these points. The indications were not such as to justify a heavy expenditure in preparing for the shipment of coal, but quite sufficiently promising to render a very careful and systematic examination of the locality desirable. This yet remains to be accomplished, not necessarily by expensive underground work, but preferably by tracing and examination, by costeening pits or otherwise, of the whole length of the outcrop of the coal-bearing horizon.

*Rennel Sound District.*—Prospecting work has been prosecuted on several creeks flowing into Rennel Sound, but this undertaking has also been at a standstill for several years. The district has been examined by several mining-engineers, who seemingly have a good deal of faith in it, claiming that a sum

* *Geological Survey of Canada*: *Report of Progress for* 1878-1879, Section B, page 76.

of £20,000 judiciously expended in putting down a few bore-holes, and making a light railway about 8 miles in length, from the coal-outcrops down to the neighbourhood of Rennel Sound (where an excellent harbour is situated), would place coal at least from one camp, upon the market. At each of these prospects, several costeening pits were sunk on the outcrops, all of which flatten in depth and take a moderate dip to the east and north-east (Fig. 7, Plate XVI.).

From the mouth of Honna river northwards, shale and sandstone-formations are found extending to the top of a mountain (1,200 feet high) 4 miles from the coast, where there is an exposure of coarse, pebbly conglomerate. Ascending geologically into the coarse sandstones of the authracite-formation, the first outcrop is found on section 17-5, and Camp Anthracite located; another outcrop occurs 200 feet farther up the creek; northward from this point, the sandy shales and finer sandstones of the other bituminous formations are found; the next outcrops occur on section 20-5, where Camp Robertson was located: and about 8 miles farther north on section 36-6, the darker shales and lighter fine sandstones of the later bituminous formations are found, in which Camp Wilson is located.

The above district lies to the east of the volcanic eruptions which have broken up the measures on the southwestern shore of Skidegate Inlet and the western coast of the island.

About 1 mile to the north-east, lignites occur, and they extend to the northern and eastern coasts. This discovery confirms the statement of Dr. Dawson that "Tertiary rocks holding lignite form a large portion of the northern portion of Queen Charlotte Island."

Mr. H. E. Parrish is of opinion, from the great thickness of the bituminous coal-bearing sandstones in the interior of Graham Island, that they must lie at such a depth on the northern and eastern coasts as to be unworkable. It is evident that the volcanic eruption of the mountain-range of the western and south-western coasts had raised the measures bearing anthracite and bituminous coals, breaking them up in the mountains and bringing them to the surface in the flanks of the foot-hills, which skirt the western and southern portions of the island.

The several costeening shafts and drifts conducted at these three respective prospects, have proved the following seams:—

*Camp Anthracite.*—Costeening shafts have been sunk along an anthracite-outcrop, proving the seam to increase in thickness from 2 feet at the outcrop to 10 feet at the face of a tunnel, 30 feet long, with the strike regular, and the dip diminishing from vertical at the surface to about 45 degrees at the foot of the shaft.

*Camp Wilson.*—The North Yakoun No. 1 bed was 13½ feet at the outcrop, the strike being north and south, and the dip vertical; and 20 feet north of the shaft, when operations were temporarily suspended, the seam had thickened to 18 feet with the same strike, but the dip had decreased to 50 degrees to the eastward. A second seam was 28 inches thick. These coal-seams are of a later formation than those found at Camp Robertson, and are free-burning bituminous coals of excellent quality, burning with a clear flame, leaving a very small percentage of ash, and requiring but little draught.

*Camp Robertson.*—This prospect is situated about 8 miles south of Camp Wilson, and about 8 miles from the mouth of Honna river. A tunnel has been driven 180 feet into the measures cutting across two seams of coal, and costeening shafts have also been sunk. At No. 1 shaft, the No. 1 Yakoun bed was 19½ feet thick, containing 18 feet of coal with a north-and-south strike and a vertical dip. At No. 2 shaft, the No. 2 Yakoun bed, dipping eastward 20 degrees, with a north-and-south strike, was 12 feet thick, containing 11 feet of coal. In another shaft, sunk 60 feet eastward of No. 1 shaft, this seam increased to 14½ feet, and contained 13½ feet of coal. The No. 3 Yakoun and overlying seam was 7½ feet thick. Mr. Parrish was of opinion that the No. 1 Yakoun bed was an excellent coking and smithy coal; that No. 2 bed was somewhat similar to No. 1 bed, but not so free from impurities; and that No. 3 bed was a somewhat freer burning coal than Nos. 1 and 2 beds. Table VIII. contains analyses of these coals.

It will be recognized that this coal compares very favourably with that from other Pacific coal-fields and as the limited area of the coal-fields of Vancouver Island is becoming rapidly exhausted, there is every likelihood that the Queen Charlotte coal will shortly be placed on the market.

In prospecting and opening this coal-field, white labour will hardly be obtainable at less than 12s. 6d. (3 dollars) a day, without board; and the standard rate of wages will probably be fixed by that prevailing at Nanaimo and the other mines on Vancouver Island, where at the present time many of the miners are averaging 25s. (6 dollars) per day.

The Camp Robertson district lies to the west and north of that prospected by the Queen Charlotte Coal-mining Company, Limited, the most extensive authracite-outcrop discovered being north of, and almost adjacent to, that first discovered, and in a seemingly much less disturbed locality.

TABLE VIII.—ANALYSES OF COALS, QUEEN CHARLOTTE ISLANDS.

| | Camp Robertson. (1) | Camp Wilson. No. 1 Seam. (2) | Camp Wilson. No. 2 Seam. (3) | Camp Wilson. (4) | Camp Anthracite. (5) |
|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent | Per cent. |
| Moisture ... ... .. | 2·64 | 2·80 | 3·04 | 1·94 | 2·14 |
| Fixed carbon ... ... | 52·86 | 62·10 | 57·23 | 59·97 | 93·72 |
| Volatile comb. matter ... | 36·76 | 30·20 | 33·33 | 36·04 | 0·78 |
| Ash ... ... ... | 7·74 | 4·90 | 6·40 | 2·05 | 3·36 |

Although the expenditure of £20,000 would probably place the coal from one camp on the market, yet, owing to the contour of the country, it would be necessary to construct 21 miles of railway to work all the camps to a shipping-point on Skidegate Inlet, and a length of 20 miles of surface-road would place all the camps in communication with a shipping point on Rennel Sound, on the western coast.

## X.—VANCOUVER ISLAND (Fig. 8, Plate XVI.).

The next coal-fields on the Pacific Coast are those of Vancouver Island, which are perhaps the oldest worked of any on the seaboard. They have been elaborately examined by the Geological Survey of Canada, (1) by Mr. James Richardson, as to the coal-fields of Nanaimo, Comox, Cowichen, Burrard Inlet and Sooke,* and (2) by Dr. G. M. Dawson, as to the northern part of Vancouver Island and adjacent coast.

*Comox and Nanaimo Districts.*—This coal-field comprises a long, narrow trough extending in three patches from the vicinity

* *Geological Survey of Canada: Report of Progress for* 1876-77, pages 60 to 192.

of Cape Mudge on the north-west to within 15 miles of Victoria on the south-east, with a length of 130 miles. This trough lies on its north-eastern side beneath the Strait of Georgia, being bounded by crystalline rocks coming apparently from beneath it in Lasqueti, Texada and other islands, and on the mainland beyond. On the south-west along the mainland, it is limited by a range of bold mountains of the crystalline series, which runs nearly parallel to the coast. This trough is separated between Wellington and Nanoose by crystalline rocks, dividing the north-western portion or the Comox coal-field, from the south-eastern or the Nanaimo coal-field.

The workable seams of coal, as proved in the Nanaimo district, have the following average sections:—

| | Ft. | Ins. |
|---|---|---|
| *Douglas Coal-seam:* | | |
| Roof—Conglomerate, 3 feet to ... | 4 | 0 |
| Black shale ... | 4 | 0 |
| Parting, *nil* to ... | 0 | 6 |
| Seam—Coal, 1 to 25 feet ... | 5 | 0 |
| Soft shale, mining dirt ... | 0 | 3 |
| Thill—Shale ... | 6 | 0 |
| Sandstone ... | ? | |
| Strata ... | 60 | 0 |
| *Wellington Coal-seam:* | | |
| Roof—Conglomerate, *nil* to ... | 12 | 0 |
| Shale, *nil* to ... | 3 | 0 |
| Seam—Coal, 2½ to 3½ feet ... | 2 | 6 |
| Thill—Sandy shale ... | ? | |

The Wellington seam furnishes a house-coal of a superior quality to that of the upper seam, which is a steam-coal. Table IX. contains analyses of these coals made by the provincial assayer, and recorded in the British Columbia Board of Trade Returns for 1899. The coke made at the Union mine contains 0·60 per cent. of moisture, 2·60 per cent. of volatile matter, 80·00 per cent. of fixed carbon and 16·80 per cent. of ash.

Several of the islands lying in the Strait of Georgia contain coal-bearing formations, and a few attempts have been made at prospecting them by bore-holes, but these enterprises have always been conducted by men with limited capital and consequently operations had to be abandoned. A few of these islands comprise the whole of the unleased portion of the coal-field, and they are owned by several private individuals.

*Modes of Working.*--At one of the most important mines, where the coal is thin, with a cover of, say, 400 feet, the mode of working practised is longwall, the gateroads being 36 feet apart. Crossgate-roads are run every 240 feet, and 12 feet packwalls are built on each side of the gateroads. On an average, about 20 gateroads are turned away from each crossgate-road. With 16 hours of working in each day of 24 hours, the working-face advances about 3 feet per shift. Brushing is required twice in the main gateroads, and once only in other gateroads, a thickness of 3 to 4 feet being taken down in order to make the required height of 7 feet. All brushing is paid by datal wage.

TABLE IX.—ANALYSES OF BRITISH COLUMBIAN COALS.

| | Union Mine. | | Extension Mine. | | Alexandria Mine. | Wellington Coal-seam. |
|---|---|---|---|---|---|---|
| | Lower Coal-seam. (1) | Top Coal-seam. (2) | Lower Coal-seam. (3) | Top Coal-seam. (4) | (5) | (6) |
| | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| Moisture ... ... .. | 1·43 | 0·80 | 1·00 | 0·75 | 1·15 | 1·90 |
| Volatile matter ... .. | 25·57 | 28·00 | 32·80 | 33·25 | 31·85 | 32·10 |
| Fixed carbon ... | 65·00 | 57·60 | 60·80 | 58·04 | 58·70 | 56·40 |
| Ash .. .. .. | 8·00 | 13·60 | 5·40 | 7·96 | 8·30 | 9·6J |
| Coking quality .. | Very fair | Very fair | Medium | Partial | Medium | Partial |

Thicker seams are worked by the pillar-and-stall system, the stalls being driven 27 feet wide, but in dip-places only 21 feet wide; the pillars are left from 35 to 55 feet by 120 feet; and the headings are driven 10 to 12 feet wide. Formerly, the pillars were only made 30 to 35 feet by 120 feet at a depth of 450 feet, but it was found that they were speedily crushed. Mines are working under the sea at a depth of 450 feet. All pillars are removed when working under the sea at a depth of 750 to 1,000 feet, but there is 100 feet of mud-silt lying on the Coal-measures. When working near a fault, 100 to 120 feet of coal is left adjacent to it on the dip side.

*Wages, etc.*—At a mine working the Douglas coal-seam, the tonnage-price is 2s. 6d. (60 cents); at mines working the Wellington coal-seam, the tonnage-price ranges between 2s. 6d. and 3s. 4d. (60 and 80 cents); headings cost from 8s. 4d. to 12s. 6d. (2 to 3 dollars): and at these rates the lowest wages were:—

Pillars, 18s. 9d. (4·50 dollars); stalls, 14s. 8d. (3·53 dollars); and longwall, 15s. 2d. (3·63 dollars). Miners are supplied with oil by the owners for 2s. 6d. (60 cents) per month, workmen live in rented houses, or shacks, and all married men are supplied with coal, but pay for leading.

Overmen are paid £24 (120 dollars) per month; fire-bosses, 13s. 6d. (3·25 dollars) per shift; timbermen and shiftmen, 12s. 6d. (3 dollars) per shift; and pushers and mule-drivers 10s. 5d. (2·50 dollars) per shift.

*Quatsino Sound.*—Almost at the northern extremity of the island, two or three other patches of Cretaceous measures are known to exist, surrounded by Triassic rocks. On the north-western arm, near Quatsino Sound, coal had been known to exist for years, this area having been reported on by the Canadian Geological Survey in 1868, and again by Dr. G. M. Dawson in the annual report for 1886. Seams of coal, 4 feet thick, were then reported. In 1897, the Hallidie Syndicate of San Francisco explored certain areas in this district, and it is reported that good coal is at present being mined from a 5 foot seam, but as yet shipping facilities are lacking.

A sample taken from an outcrop in another locality in this district given to the writer by Mr. Bury of Victoria, British Columbia, and submitted by him to Mr. W. F. Robertson, the provincial mineralogist, was analysed as follows:—

| | Per cent. |
|---|---|
| Moisture ... ... ... ... .. | 9·1 |
| Volatile matter ... ... ... ... | 27·4 |
| Fixed carbon ... ... ... ... | 50·6 |
| Ash ... ... ... ... ... ... | 12·9 |

There is no doubt, if a good coking coal were found on this coast, that it would offer very advantageous opportunities for smelting, provided the ore-bodies proved of sufficient extent and grade.

*West Arm and Rupert Arm.*—Another small area of Cretaceous measures exist on the West Arm and Rupert Arm, midway between the western and eastern coasts of the island.

*Sukwash and Port McNeill.*—A third patch, on the eastern

coast between Port McNeill and Alert Bay, has been examined by the officers of the Geological Survey of Canada, by Dr. Dawson, and again in 1889 by Mr. A. L. Poudrier.

This coal-field belongs to the Sukwash coal-measures, assignable, in Sir Wm. Dawson's opinion (owing to fossils found in large quantities near Port McNeill), to a lower and older horizon than the coal-fields worked at Comox and Nanaimo. The productive formation starts at a fault at the north-eastern end of Port McNeill, and extends along the coast to Beaver harbour, a distance of about 14 miles. Coal was found as early as 1835 at Sukwash, and the Hudson Bay Company is reputed to have worked 10,000 tons from a 4 feet seam, but the discovery of coal at Nanaimo stopped further exploration. The Hudson Bay Company abandoned this district in 1854 (after spending a considerable sum in prospecting), shifting their plant and machinery, and starting the Nanaimo mine, now owned and worked by The New Vancouver Coal and Land Company.

Mr. Grant stated that in 1840, a shaft was sunk about 6 miles from Sukwash and ½ mile from Fort Rupert, to a depth of 90 feet by Mr. Muir for the Hudson Bay Company who found the seems too thin; and another shaft was sunk to a depth of 120 feet, at Fort Rupert by Mr. Gilmour. A bore-hole was sunk directly at the back of Fort Rupert to a depth of 285 feet: and two others were put down behind Fort Rupert and towards the interior: one about 4 miles to the north-west, where the borers were stopped by loose quicksand at a depth of 180 feet; and the other to a depth of 240 feet, about 2 miles to the south-west. Again, 10 miles from Fort Rupert along the sea-coast, two bore-holes were sunk through sandstone to depths of 282 and 285 feet respectively, without any signs of workable coal, these holes being sunk some distance back from the shore. But, close to the shore, two shafts were sunk 102 and 180 feet respectively, the thickest seam that was struck, however, did not exceed 6 inches.

According to Mr. Poudrier, several thin coal-seams, varying from 5 to 15 inches in thickness, are seen cropping out along the shore; and on the Chickseeway river, a seam of 18 inches of coking coal has been found in association with about 2 feet of coaly shale. This seam runs eastward, and lies very level, with a dip of 12 degrees. An analysis of this coal made by Dr. Harrington, of the Geological Survey of Canada, was as follows:—

| | (1) Fast coking. Per cent. | (2) Slow coking. Per cent. |
|---|---|---|
| Water ... ... | 2·84 ... | 2·84 |
| Volatile matter ... | 39·23 ... | 33·56 |
| Fixed carbon ... | 46·36 ... | 52·03 |
| Ash ... ... ... | 11·57 ... | 11·57 |

Other coals were analysed by Mr. Hoffmann as follows:—

| | (1) Per cent. | (2) Per cent. | (3) Per cent. |
|---|---|---|---|
| Water ... .. | 5·03 ... | 3·65 ... | 3·68 |
| Volatile matter ... | 41·51 .. | 42·23 ... | 39·29 |
| Fixed carbon ... | 46·52 . | 39·84 ... | 47·03 |
| Ash ... ... | 6·94 ... | 14·28 ... | 10·00 |

*Saanich District.*—Another small detached area of Cretaceous formation is seen overlying the shores of Saanich peninsula, which is supposed by Mr. Richardson* to belong to the Cowichen district of the Nanaimo coal-field, and is situated by water about 20 miles to the north of Victoria. The writer has thoroughly examined this district, as well as several of the adjoining islands, which also contain Cretaceous rocks.

Along the western shores of Saanich peninsula, although coal-seams are not seen cropping out in the bluffs, Cretaceous sandstones are found overlying the crystalline rocks at Boulder Point, and at intervals containing indications of either carbonaceous shales or coal-seams, the measures having a uniform strike varying from north 63 degrees west to north 70 degrees west, with a dip varying from 12 to 24 inches per yard. The land, including coal-rights, is cut into sections of 100 acres, and consequently is owned by several individuals, a few of whom have sunk wells on their property, and also have carried out a little prospecting individually. In one of these sections on the shore, where a shaly streak was found, 1 inch thick, two miners, some years ago, sank a shaft, and found that the seam thickened to 2½ feet of inferior coal, at a depth of 120 feet; but the shaft was ultimately drowned out and abandoned. Another well, examined by the writer, was one sunk on Mr. Coupland's farm, situated about ½ mile south of the extremity of the peninsula, and midway between the western and eastern shores, which passed through: Boulder-clay and gravel, 10 feet; blue metal, with fossil-ferns and a little water, 10 feet; and coaly shale, 2½ feet. The writer picked up two or three pieces of coal on the surface, which had come out of this

* *Geological Survey of Canada: Reports of Progress for* 1872-74 and 1875.

well, and these were analysed through the courtesy of Mr. W. F. Robertson of Victoria, the provincial mineralogist, as follows:—

| | Per cent. |
|---|---|
| Moisture ... ... ... ... ... | 2·00 |
| Volatile matter ... ... ... .. | 33·50 |
| Fixed carbon ... ... ... ... | 49·50 |
| Ash ... ... ... ... ... ... | 15·00 |

If this bed improved in depth, there seems a probability that the Nanaimo coals would exist under the edge of the Saanich peninsula, in an area of not more than 2,500 acres lying in the shape of a horse-shoe, owing to crystalline rocks cropping out on the surface and forming a backbone between the western and eastern coasts of the peninsula.

## XI.—Crows Nest Pass Coal-field, British Columbia.

*Geology.*—Although this coal-field is situated 375 miles inland due east from the coast, yet, owing to the thickness of the coal-seams and to the fact that the quality of these coals far surpasses the majority of those found on the Pacific coast, within the last few years the mines have been rapidly developed (Fig. 5, Plate XVI.).

This coal-field is situated in the Fort Steele mining district, about 40 miles north of the international boundary, and was reported on by Dr. Selwyn in 1891, who estimated its area at not less than 144 square miles, and who furnished sections of twenty coal-seams, with a thickness of 132 feet of coal, at Fernie, near where the Crows Nest Pass Coal Company commenced operations (Table X.).*

Table X.—Coal-seams occurring at Fernie.

| No. | Description of Seam. | Feet. | No | Description of Seam. | Feet. |
|---|---|---|---|---|---|
| 1 | Cannel-seam ... ... ... | 5 | 11 | Cannel-seam ... ... | 4 |
| 2 | ,, .. ... ... | 3 | 12 | Peter coal-seam ... ... | 15 |
| 3 | ,, ... .. ... | 4 | 13 | Coal-seam ... ... ... | 7 |
| 4 | ,, ... ... ... | 2 | 14 | Selwyn coal-seam ... .. | 6 |
| 5 | ,, ... ... .. | 4 | 15 | Jubilee coal-seam ... | 30 |
| 6 | ,, .. ... ... | 3 | 16 | Williams coal-seam .. | 20 |
| 7 | ,, ... .. ... | 2 | 17 | Cannel-seam ... ... | 5 |
| 8 | ,, ... .. ... | 4 | 18 | ,, ... ... | 3 |
| 9 | ,, ... ... ... | 5 | 19 | ,, ... ... | 2 |
| 10 | ,, ... . ... | 6 | 20 | ,, ... ... | 2 |

Mr. J. McEvoy limits the probable working thickness of coal to 100 feet, and estimates the total available coal at 22,000,000,000 tons. This opinion is endorsed by Mr. William Blakemore, of

* *Geological Survey of Canada: Annual Report for 1890-1891*, 1893, ss., page 61.

Montreal, on whom has devolved the major share of opening up this field. He contends that the number of workable bituminous seams will not be more than eight or ten, with an aggregate thickness of 120 feet, as the seams of cannel enumerated in Table X. have been proved to be bituminous shale, and should therefore be eliminated.

It is reported that recent explorations in Alberta at the entrance to the Crows Nest Pass, confirmed by the opinion of the officers of the Canadian Geological Survey, have proved that these seams exist over an additional area east of the Rocky Mountains, at least 20 to 25 miles wide, together with additional coal-seams, owing presumably to the fact that in these mountains many of the upper coal-seams have been destroyed by erosion. The discovery of this new field caused great activity in Western Alberta, between Fort McLeod and the Rocky Mountains, this last summer, and areas covering probably 300 square miles were taken up. But although some coal has been discovered on most of these claims, with two or three exceptions, the coal is much disturbed, the measures being twisted and tilted to such an extent that the continuity of any seam is traced with difficulty.

In the Pass, the seams are found along a low synclinal with eastern and western outcrops, and the strike of the coal-belt approximates to due north and south, with a dip varying from level to 20 or 25 degrees; but in the new field the seams are found uniformly dipping to the west at angles of 55 to 60 degrees, with sandstone-rocks and shales intervening.

Near Blairmore, on the Canadian Northern Pacific Railway, and about 18 miles east of the Crows Nest summit, an interesting property is being developed by Messrs. Gebo and Franks. They are opening, in the Lower Cretaceous formation, a seam of clean bright coal, 14 feet thick, lying vertical, having been forced into that position by a great limestone upheaval running for many miles north and south, and parallel to the main range of the Rocky Mountains. On the western side, it is separated from the limestone by a few feet of shale, but on the eastern side the wall is a greyish sandstone. It is stated that the seam preserves unbroken continuity for 4 miles, and an average altitude of 500 feet on the mountain-side above the level of the surrounding country, will contain a large tonnage above water-level. How far the seam extends downward is at present doubtful, as the shelving base of

the mountain may cut it off at a short distance, but a shaft is being sunk to the coal.

*Analyses.*—Analyses of samples of coal taken from two seams in the Fernie district of the Pass and made by Mr. G. C. Hoffmann, Geological Survey of Canada, are shewn in Table XI.

TABLE XI.—ANALYSES OF COALS OF CROWS NEST COAL-FIELD.

| | Peter Seam. | | Jubilee Seam. | |
|---|---|---|---|---|
| | Slow coking. Per cent. | Fast coking. Per cent. | Slow coking. Per cent. | Fast coking. Per cent. |
| I. Approximate analyses— | | | | |
| Water ... ... | 1·79 | 1·79 | 1·89 | 1·89 |
| Volatile matter ... | 25·45 | 33·04 | 24·88 | 30·41 |
| Fixed carbon ... ... | 69·14 | 61·55 | 68·86 | 63·33 |
| Ash ... ... ... | 3·62 | 3·62 | 4·37 | 4·37 |
| Coke per cent ... | 72·76 | 65·17 | 73·23 | 67 70 |
| II. Ultimate analyses— | | | | |
| Carbon ... ... | 80·51 | 85·57 | 80·04 | 85·82 |
| Hydrogen ... .. | 5·20 | 5·53 | 4·94 | 5·30 |
| Oxygen and nitrogen ... | 8·37 | 8·90 | 8·28 | 8·88 |
| Sulphur ... ... | 0·51 | — | 0·48 | — |
| Ash ... ... .. | 3·62 | — | 4·37 | — |
| Water .. ... ... | 1·79 | — | 1·89 | — |

An analysis of coal from the Alberta field is recorded as follows:—

| | Per cent. |
|---|---|
| Moisture ... ... ... ... ... | 0·1 |
| Volatile matter ... ... ... ... | 29·1 |
| Fixed carbon ... ... ... ... | 63·4 |
| Ash ... ... ... ... ... ... | 7·4 |
| Coke ... ... ... ... ... ... | 70·8 |
| Sulphur ... ... ... ... ... | 3·6 |

The coals from the Alberta field have been tried for steaming purposes, and yielded results not much inferior to the Fernie coal: but for coking-purposes the latter coal is superior. The best Alberta coal, producing from 55 to 60 per cent. of coke contains 12 to 20 per cent. of ash, against an average of 72 per cent. of coke with Fernie coal.

## XII.—KAMLOOPS AND THE SIMILKAMEEN AND NICOLA VALLEYS, BRITISH COLUMBIA (Fig. 5, Plate XVI.).

During 1900, coal was found near Kamloops, in the Yale district, and in the Nicola valley of the Similkameen mining division.

but it is not likely to compete seriously with any of the coals of the Pacific coast or of the Crows Nest Pass.

*Kamloops.*—Coal is being sought at a point where the late Dr. Dawson indicated that an extensive deposit might be found, being the continuation of the seam occurring at Coal Hill, but which at that point was not of sufficient thickness.

On the eastern side of North Thompson river, about 50 miles from Kamloops, in the vicinity of the Indian reservation, a coal-mine exists and 200 tons of excellent coal have been wrought. but owing to the thinness of the seam the mine has been closed.

*Nicola Valley.*—Another find of a seam, 10 feet thick, was reported near Otter Flat, and samples of the coal have been analysed as follows:—

| | Per cent. |
|---|---|
| Volatile matter ... ... ... ... | 37·2 |
| Fixed carbon ... ... ... ... | 58·0 |
| Ash ... ... ... ... ... ... | 4·8 |

The coal is stated to be suitable for raising steam, and for coking.

Extensive deposits of non-titaniferous magnetite have been discovered in the vicinity of this coal-field, containing 54 per cent. of metallic iron.

*Similkameen Valley.*—On the banks of the Similkameen river, opposite Princeton, a coal-seam, about 6 feet thick, has been opened by a tunnel about 100 feet long. This seam has a slate-roof and a sandstone-floor, and has a nearly flat dip towards the south, but as the seam occurs at the summit of a local anticlinal fold, it dips also about 30 degrees towards both east and west. The surface outcrops and for some distance under cover in this tunnel, showed a poor quality of coal, but towards the breast of the tunnel the quality improved and samples have been analysed as recorded in Table XII.

TABLE XII.—ANALYSES OF LIGNITE FROM THE TUNNEL OF THE VERMILLION FORKS MINING AND DEVELOPMENT COMPANY.

| | Per cent. | Per cent. | Per cent. | Per cent. |
|---|---|---|---|---|
| Moisture ... ... | 5·0 | 5·0 | 4·8 | 4·5 |
| Volatile matter ... | 39·0 | 36·0 | 39·2 | 34·5 |
| Fixed carbon ... | 49·0 | 53·0 | 49·0 | 50·5 |
| Ash ... ... | 7·0 | 6·0 | 7·0 | 10·5 |

*Babine and Bulkley Rivers: Skeena Mining District.*—Coal-prospects have also been found on the banks of these rivers but, owing to the remoteness of this coal-field, its value both to the country and to the owners is only a reserve and a guarantee for the future opening up of this section of the country.

### XIII.—Puget Sound Coal-field, State of Washington, U.S.A.

Another coal-field, which has been developed within the last few years, is the Puget Sound basin situate in the State of Washington, U.S.A. It lies on either side of the meridian of 122 degrees, extending 10 miles east and 10 miles west with irregular outline from north to south, stretching through less than a degree of latitude from near 47 degrees 35 minutes to about 46 degrees 45 minutes north. The productive portion of this field lies from 7 to 25 miles east and south-east from, and extends parallel to the south-eastern inlet which ends in Commencement Bay: and the western foot-hills and western valleys of Mount Rainier the huge extinct volcano, reach into the southern portion of this area of coal-bearing rocks. The mines are connected by railways, 12 to 35 miles in length, with the cities of Seattle and Tacoma. The fields, so far as at present known, can be divided up into the following districts, namely:—(1) Newcastle-Gilman district; (2) Renton-Cedar river district; (3) Green river district; and (4) Wilkeson-Carbonado district. These four districts have been examined for the United States Geological Survey by Mr. Bailey Willis.*

*Geology.*—There is some doubt as to the geological age of the Puget coal-measures, owing to the obscurity of the stratigraphic relations, the general absence of marine fauna, and the indeterminate character of the flora. Dr. Newberry correlated a collection of fossils made prior to 1884 with the Laramie (Cretaceous), and the series has been dated as late Cretaceous, or early Eocene. Collections made in 1895 and 1896 from the Green river and Carbonado districts were submitted to Mr. Knowlton, who stated that the lower beds of the series are of Eocene, and the upper beds may be of Miocene age.

* "Some Coal-fields of Puget Sound," *Eighteenth Annual Report of the United States Geological Survey, 1896-97*, 1898, part iii., pages 393 to 436.

Owing, however, to extensive eruptions, dividing the area of the field into several districts, which are so separated as to make it impossible to identify their stratigraphic relations; and owing also to the present absence of fossils, this field may be divided into four groups of rocks, which may be classed as follows:—

(1) Metamorphic schists and limestones of Carboniferous or Jura-Trias age, upon which the Puget group was deposited unconformably, at least, in the Skagit district.

(2) Marine Miocene or Tejon, with which the Puget group is stratigraphically continuous.

(3) Tertiary eruptives, which are younger than the Puget group and date down to the Pleistocene.

(4) Glacial gravel-deposits of Pleistocene age.

Measured sections of the Puget group have total thicknesses of 5,800 feet on the Green river, 5,500 feet on South Prairie creek, and 5,480 feet in Carbon river canyon, but none of them are complete, as, in each case, the lowest stratum is of the Puget group outcropping on an anticline, and the highest is the limit of exposure, where the rocks pass under later formations. These sections overlap, and as higher beds are exposed on South Prairie creek above the limit of the measured sections, the thickness of the entire group might be 9,000 feet or more.

*Newcastle-Gilman District.*—The valley of Issaquah creek, which flows northward through Squak Mountain into Sammamish Lake, lies 15 miles east of Seattle, beyond Lake Washington. Squak Mountain has a height of 1,980 feet, and at an elevation of 1,000 feet sends off a bold spur to the northward. North-west of Squak Mountain, a range of hills rising to a height of 1,500 feet extends for 5 miles between Lake Washington and Sammamish. The Newcastle mines are situated on the western slope of these hills, while the Gilman mines are located in the northern spur of Squak Mountain, about 1 mile south and 5 miles east of the Newcastle mines. Both these districts are served by circuitous lines of railway from Seattle; but there is no direct connection, except by trail, between these two mining points. There are resemblances between the seams of the two sections, and it is supposed that they represent opposite sides of the coal-basin. If this be so, the coal-bearing district must occupy an area of not less than 5 square miles, and may extend over 12 square miles.

A general section at the Gilman mines is shewn in Table XIII. The strike is south 86 degrees west, and the dip varies from 20 to 40 degrees.

TABLE XIII.—SECTION OF STRATA AT THE GILMAN MINES.

| Description of Strata. | Ft. | Ins. | Description of Strata. | Ft. | Ins. |
|---|---|---|---|---|---|
| No. 4. Vein, the highest of the known series ... .. | 7 | 0 | Strata .. ... ... .. | 175 | 0 |
| Strata ... ... ... ... | 300 | 0 | No. 1 Vein ... ... ... | 16 | 0 |
| No. 3 Vein ... ... ... | 5 | 0 | Strata ... ... ... ... | 412 | 0 |
| Strata ... ... ... ... | ? | | No. 5 Vein ... ... ... | 8 | 0 |
| No. 2 Vein ... ... ... | 6 | 0 | Strata ... ... ... ... | 360 | 0 |
| | | | No. 6 Vein ... ... ... | ? | |

*Green River District.*—Midway between the cities of Seattle and Tacoma, and 15 miles east of a line connecting them lies the Green river district: and its westernmost development, the Black Diamond mine, lies 11 miles due east of Auburn on the Northern Pacific railway. These coal-outcrops attracted attention in 1880, and led to a good deal of prospecting, which proved a single, well-defined coal-basin, followed and traced out near the western edge of the field, upon which the Franklin, opening on Green river, and the Black Diamond mine, 3 miles farther north-west, were located, and placed in communication with the Northern Pacific railway. Other operations were begun to the east and south-east, but the lie of the coal in that tract has never been accurately determined, and no mines comparable to those mentioned have been developed.

A section of strata exposed on Green river* enumerates 40 beds of carbonaceous character, but only four (Nos. 14, 15, 18 and 23) are productive coal-seams lying within the Franklin district: Nos. 1 to 12 veins belong to the lower measures, which are exposed to the north and east of the Franklin collieries: and No. 18, also known as the McKay or Light-ash or White-ash vein, 20 feet thick, is now extensively worked by the Franklin, Black Diamond and the Light-ash mines, from which the principal supplies of steam-coal are drawn.

The stratigraphy of the Green river coal-field bears some resemblance to that of the Wilkeson-Carbonado district, but the structure is more simple, there being a direct stratigraphical relation between the moderately developed folding and the moderately concentrated condition of the coal-seams. Towards the east, where the measures are more complex and the development of the

* *Tenth Census Reports*, vol. xv., plate LXXXI.

folds is the result of greater compression, the coal-seams of the Green river field are highly bituminous, while towards the north-west, where the degree of compression and movement was less, the coal-seams are really lignites.

*Wilkeson-Carbonado District.*—This district lies south-east of Puget Sound, on the extreme north-western foot-hills of Mount Rainier, the mines being about 20 to 23 miles distant from the city of Tacoma, and the western limits are determined by the gravel-plateaux of the Puget Sound drift. The northernmost mines are opened on South Prairie creek at Burnett, 2 miles south of which are the Burnett mines, and the Carbonado mines are 2 miles to the south-west from the Wilkeson, all these mines lying in the extreme northern portion of the coal-field.

The southern districts, although prospected in the years 1883 and 1884, have remained undeveloped on account of their inaccessibility. The portion of the field concerning which there is most information, and which is likely to become important in the immediate future, lies between the Wilkeson and Carbonado mines.

The geology of this district presents a most difficult problem, there being no continuous outcrops from one mine to another, and each group of mines exposes a different section of strata.

On South Prairie creek, above Burnett, a series of sandstones and shales are exposed, aggregating 4,770 feet, containing five beds of inferior coal near the top of the section, the Burnett vein 4½ feet thick being the lowest. And 84 feet above this seam occurs a massive bed of sandstone interbedded with shale, about 940 feet thick, designated as the Wilkeson formation, below which are the productive Coal-measures known as the Carbonado formation. The Wilkeson sandstone is overlain by the Pittsburg formation, and these measures can be traced eastward with an uniform dip, and with a thickness of 4,000 feet exposed to the westward on the creek.

The exposures at Wilkeson do not afford any continuous section, showing, along the line of railway, sandstone-bluffs with occasional outcrops of coal and bone, evidently representing the Pittsburg formation of South Prairie creek. But for a section of the workable seams in this portion of the field, it is necessary to accept that exposed in a cross-cut tunnel, about 1½ miles further

south, where, in the course of mining, a series of seams have been cut, the upper one evidently lying within the Wilkeson sandstone.

In the Carbonado district, Mr. Bailey Willis seemingly found a difficulty in correlating the seams worked at Carbonado with those at Wilkeson, but from his observations of strike and dip, he assumed the existence of an anticlinal axis pitching northward. The sequence of strata from the Wingate vein upward includes a series of massive sandstones, in which is the Miller vein, a thick, dirty coal-seam, with a section that closely compares with that of the Burnett or Hill vein. The mines in each of the three districts are connected by railroad with the port of Tacoma.

TABLE XIV.—CORRELATION OF THE CARBONADO AND WILKESON SECTIONS.

| CARBONADO DISTRICT. | | | WILKESON DISTRICT. | | |
|---|---|---|---|---|---|
| Description of Strata. | Ft. | Ins. | Description of Strata. | Ft. | Ins. |
| Wingate Vein ... ... ... | 4 | 0 | Burnett No. 1 or Hill Vein ... | 4 | 0 |
| Strata .. ... | 304 | 0 | Strata .. ... . ... | 230 | 0 |
| No. 2 and No. 5 North Veins... | 5 | 0 | Burnett No. 4 or Bobby Vein... | 5 | 0 |
| Strata .. .. .. ... | 176 | 0 | | | |
| No. 4 South Vein ... ... | 7 | 0 | | | |
| Strata ... ... ... ... | 107 | 0 | | | |
| Bony Coal ... ... ... | 9 | 0 | Strata not proved ... ... | 500 | 0 |
| Strata .. ... ... ... | 105 | 0 | | | |
| Coal-seam... ... ... ... | 1 | 0 | | | |
| Strata ... ... ... ... | 120 | 0 | | | |
| No. 3 South Vein ... ... | 3 | 6 | Gopher or Wilkeson No. 3 Vein... | 2 | 6 |
| Strata .. ... ... ... | 12 | 0 | Strata ... ... ... ... | 15 | 0 |
| No. 5 South Vein ... ... | 5 | 0 | Bogus Vein ... ... ... | 12 | 0 |
| Strata ... ... ... ... | 20 | 0 | Strata ... ... .. ... | 20 | 0 |
| Coal-seam .. ... ... ... | 2 | 0 | Coal-seam... ... ... ... | 2 | 0 |
| Strata ... ... .. ... | 244 | 0 | Strata . ... ... ... | 96 | 0 |
| No. 7 South Vein ... ... | 7 | 6 | Wilkeson No. 2 Vein ... ... | 9 | 0 |
| | 1132 | 0 | | 895 | 6 |
| Strata ... ... ... ... | ? | | Strata ... ... ... ... | 52 | 0 |
| No. 8 Vein ... ... ... | 2 | 3 | No. 1 Coal-seam.. ... ... | 6 | 0 |
| | | | Strata ... ... ... ... | 5 | 0 |
| | | | Coal and bone ... ... ... | 5 | 0 |
| Strata ... ... ... ... | ? | | Strata ... ... ... ... | 140 | 0 |
| | | | Bony Coal ... ... ... | 4 | 0 |
| | | | Strata ... ... ... ... | 41 | 0 |
| | | | Bone and Coal ... ... ... | 1 | 0 |
| | | | Strata ... ... ... ... | 143 | 0 |
| No. 10 Vein, in tunnel ... ... | 6 | 2 | No. 7 or Kelly Vein ... ... | 21 | 6 |
| | | | Shale ... ... ... ... | 13 | 0 |
| | | | No. 6 Vein ... ... .. | 6 | 0 |
| | | | Strata ... ... ... ... | 64 | 6 |
| | | | No. 5 Vein ... ... ... | 4 | 6 |
| | | | Sandstone... ... .. ... | 34 | 0 |

The Carbonado section recorded in Table XIV. may be incomplete owing to the omission of beds of black shale or bone, which may represent workable coal-seams of the Wilkeson district. The Wilkeson section is complete, from the lowest coal-seam up to the

vein worked in No. 3 mine: and there is a gap, from No. 3 vein up to the Burnett No. 1 vein, which can be only bridged over by inference. It is probable that the outcrop of the Gopher vein is on the strike of the No. 3 vein, and it bears some resemblance to the upper part of that seam. Above the Gopher vein is an interval of 500 feet or more, extending to the Bobby vein, which is correlated with the Burnett No. 4 vein. Above the Bobby vein, there is an interval of 230 feet to the Hill vein, which is considered to represent the Burnett No. 1 vein and also the Wingate vein.

*Analyses.*—The coals from different districts of Puget Sound range from lignites, the representative analyses of which have the following limits:—Moisture, 8 to 12 per cent.: volatile hydrocarbons, 35 to 45 per cent.; and fixed carbon, 30 to 45 per cent. In bituminous lignites or steam-coals, the moisture is reduced to 5 per cent. or less, and the fixed carbon ranges from 40 to 50 per cent. In bituminous coking-coals, the moisture ranges from 1 to 3 per cent.; the volatile hydrocarbons, 25 to 35 per cent.; and fixed carbon, 50 to 60 per cent. The ash often exceeds 10 per cent. in the marketable product; but as the earthy constituents occur in distinct streaks in benches of purer coal, the proportion which goes to market is determined by the cost of removing the associated bone and slate. The lignites are hard; the bituminous lignites of the Green river district are softer, but still firm: the bituminous coking-coals of the Wilkeson field are very soft; the two former may be cleaned by hand-picking, but the last-named requires washing.

## XIV.—General Comparison of Pacific Coast Coals.

According to the reports of the Board of Trade of British Columbia for 1900, the output of coal for that province was 1,590,179 tons; 150,584 tons were converted into coke producing 85,149 tons; and 914,183 tons of coal and 51,757 tons of coke were exported.

The Vancouver Island collieries produced 1,383,376 tons of coal: 47,353 tons were used for coke-making, producing 19,234 tons of coke; and 906,215 tons of coal and 12,799 tons of coke were exported.

The coal was shipped at the ports of Nanaimo, Departure Bay and Union (near Comox) and exported principally to San Francisco, San Pedro and San Diego, in California, U.S.A.: but shipments were also made to the States of Oregon and Washington, and Alaska, the Hawaiian Islands, and the steamships engaged in the China and Australian shipping-trade are important and steadily increasing consumers. The United States customs impose a duty of 1s. 8d. (40 cents) per ton on all foreign coal imported into their territory.

It is probable that shipments of Vancouver Island coal into California may remain stationary, by the substitution of petroleum as fuel, owing to the recent discoveries of oil in Texas, a region entirely devoid of mineral fuel, the Southern Pacific Railway for example having no coal along its 2,500 miles length of line. This detrimental influence on the coal-trade will, however, depend on the duration of the oil-flow.

The Crows Nest Pass collieries produced 206,803 tons of coal. but 103,231 tons were used for coke-making, producing 65,915 tons of coke. The exports to the United States included 7,968 tons of coal and 38,958 tons of coke. The Great Northern Railway, require 4,000 tons per day: nearly 1,000 tons of coke per day are used by the smelters in Montana: and, in addition, this field will supply at least two smelters in British Columbia, so that there is every indication that the output from this field will materially increase during future years. This coke, owing to its rich quality, has replaced Vancouver Island coke in the smelters in the Kootenay district, but it is questionable whether these coals can successfully compete, for the coast trade, with the good coals found on the coast, owing to the enormous distance (and consequently heavy freight rate) at which they occur from any port thereon; although in point of quality they are superior to the majority of the coals worked on the coast.

The sources of coal-supply for the State of California from 1897 to 1900 are shown in Table XV.

There was delivered in 1900 by water at the southern ports of California, namely Los Angeles and San Diego, 165,965 tons of coal, principally from British Columbia. During 1900, California imported 41,741 tons of coke, about 12,000 tons being derived from British Columbia (the product of the Comox coke-ovens) against about 4,000 tons imported from Comox in 1899.

The analyses of samples of coal from Queen Charlotte Island seem to compare very favourably with those of Vancouver Island. If they could be economically placed on the market in the neighbourhood of Rennel Sound, where there is good harbourage and deep water: and if quick despatch could be given (to accomplish this at least for one of the mines it would only at the outset be necessary to build about 7 miles of railway), there is no doubt that this coal-field should compete with that of Vancouver Island, for a share of the trade of the United States, and should also command a share of the bunkering trade of the coast.

TABLE XV.—COAL-SUPPLY OF CALIFORNIA, U.S.A.

| Sources. | 1897. | 1898. | 1899. | 1900. |
|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Tons. |
| British Columbia ... ... ... | 558,372 | 651,208 | 623,133 | 766,917 |
| Australia ... ... ... | 281,666 | 201 931 | 139,333 | 178,563 |
| England and Wales ... ... | 107,967 | 75,115 | 93,263 | 54,099 |
| Scotland ... ... .. .. | 4,081 | 5,056 | ... | ... |
| U.S.A., Eastern, Cumberland and Anthracite . ... | 21,335 | 37,560 | 38,951 | 17,319 |
| ,, Washington, Seattle ... | 220,175 | 283,963 | 271,694 | 250,590 |
| ,, ,, Tacoma ... | 286,205 | 348,474 | 355,756 | 418,052 |
| ,, Mount Diablo, Coos Bay and Tesla ... ... | 115,150 | 172,506 | 189,507 | 160,915 |
| Japan and Rocky Mountains ... | 6,587 | 26,560 | 28,390 | 42,673 |
| Totals .. ... | 1,601,538 | 1,802,373 | 1,740,027 | 1,889,128 |

Analyses of the Chilcat or Kiak coals prove that they are superior to any found on the coast, owing to their high percentage of carbon: if they were successfully placed at a good harbour, they should also be competitors for a portion of the coal-trade of the United States; and, as the district forms a portion of the United States, the coal would be exempt from the 1s. 8d. (40 cents) importation duty. Its superior quality will also probably deter if not altogether prevent the mining of the lignites of Cook Inlet. Unless the coal is shipped southward, this district lies too far to the north to catch the bunkering trade of the steamers engaged in the China service, although it would catch the bunkering trade of the Alaskan coast.

The reports made by the officers of the Geological Survey of Canada prove the extent and quality of the seams recently found east of the Rocky Mountains, at Kamloops, and in the Nicola and Similkameen valleys and also about Babine up the Skeena

river, but owing to their distance inland, even should their quality be superior, they are not likely to compete against the best of the coast coals.

Owing to the absence of coal-areas and the scarcity of timber in the mineral mining-regions of Alaska, to the existence of salmon-canneries along the coast, and also to the likelihood of smelters being required, there is no doubt that there will be a steadily increasing future demand for coal in these districts.

Although the gold-mining camp at Cape Nome on the Behring Sea has only been recently discovered and developed during the last two years, yet owing to the absence of any harbour and its openness therefore to the full force of the gales, the natural probability is that this port will never be greatly in use. However, there is every likelihood that Teller on the bay of Fort Clarence, 100 miles to the north-west of Nome, will become a permanent mining-camp, opening up an immense area of placer-ground. The country is barren of timber, and fuel would be imported from some of the coal-fields of the coast. At Cape Nome, in the latter part of 1899, coal was sold at £25 (125 dollars) per ton, but during the summer of 1900, it fell to £8 (40 dollars) per ton, although after the great storm of last September it rose to £20 (100 dollars) per ton, the whole of the supply being sent from the United States or Vancouver Island. It may be mentioned that at the Reindeer station at Cape York to the north of Port Clarence, four years ago, the missionaries could buy coal from the whalers, delivered on the beach, at £2 10s. (12 dollars) per ton, but this price has increased to that previously mentioned since the gold-rush has turned in their direction.

Comox and Wellington coal (Vancouver Island) can be bought, free on board, for about 14s. (3½ dollars) per ton, and is shipped to the Alaskan ports, namely:—Orca, Valdez, Unalaska, St. Michaels, etc., by the steam-whaling companies, and retailed at £2 to £3 (10 to 15 dollars) per ton. At Unalaska, it is retailed for bunkering at £2 10s. (12 dollars) per ton, or in 50 ton lots at £2 5s. (11 dollars) per ton, and thus it will be seen that even with high-priced labour and the cost and difficulty of opening, a margin of profit should be realized where the undertaking is carefully, judiciously and economically managed.

## APPENDIX A.—LAWS FOR GRANTS OF COAL-LANDS IN THE WESTERN UNITED STATES.

2347. *Legal Sub-division.*—Every person above the age of 21 years, who is a citizen of the United States, or who has declared his intention to become such, or any association of persons severally qualified as above, shall upon application to the registrar of the proper land-office have the right to enter, by legal sub-division, any quantity of vacant coal-lands of the United States, not otherwise appropriated or reserved by competent authority, not exceeding 160 acres to each individual person, or 320 acres to such association, upon payment to the receiver of not less than 10 dollars [£2] per acre for such lands where the same shall be situated more than 15 miles from any completed railway, and not less than 25 dollars [£5] per acre for such lands as shall be within 15 miles of such road. [Section 1, March 3, 1873.]

2348. *Settlers preferred.*—Any person or association of persons severally qualified as above provided, who have opened or improved, or shall hereafter open and improve any coal-mine or mines upon the public lands and shall be in actual possession of the same, shall be entitled to a preference-right of entry, under the preceding section, of the mines so opened and improved, provided that when any association of not less than four persons, severally qualified as above provided, shall have expended not less than 5,000 dollars [£1,000] in working and improving any such mines or mine, such association may enter not less than 640 acres, including such mining improvements. [Section 2, ld.]

2349. *Land-office Proceedings.*—All claims under the preceding section must be presented to the registrar of the proper land-district within 60 days after the date of actual possession and the commencement of improvements on the land by the filing of a declaratory statement therefor; but when the township-plot is not on file at the date of such improvement, filing must be made within 60 days from the receipt of such plot at the district office; and where the improvements shall have been made prior to the expiration of 3 months from the 3rd day of March, 1873, 60 days from the expiration of such 3 months shall be allowed for the filing of a declaratory statement, and no sale under the provision of this section shall be allowed until the expiration of 6 months from the 3rd day of March, 1873. [Section 3, ld.]

2350. *Entry Limited.*—The three preceding sections shall be held to authorize only one entry by the same person or association of persons, and no associations of persons, any member of which shall have taken the benefit of such sections, either as an individual or as a member of any other association, shall enter or hold any other lands under their provisions; and all persons, claiming under section 2348, shall be required to prove their respective rights and pay for the lands filed upon within one year from the time prescribed for filing their respective claims, and upon failure to file the proper notice or to pay for the land within the required period, the same shall be subject to entry by any other qualified applicant. [Section 4. ld.]

2351. *Conflicting Claims.*—In case of conflicting claims upon coal-lands, where the improvements shall be commenced after the 3rd day of March, 1873, priority of possession and improvements, followed by proper filing and continued good faith, shall determine the preference-right to purchase, and also where improvements have already been made prior to the 3rd day of March, 1873, division of the land claimed may be made by legal sub-divisions to include as near as may be the valuable improvements of the respective parties. The Commissioner of the General Land-office is authorized to issue all needful rules and regulations for

carrying ,into effect the provisions of this and the four preceding sections [Section 5, Id.]

2352. *Vested Right.—Lodes and Placers excepted.*—Nothing in the five preceding sections shall be construed to destroy or impair any rights which may have attached prior to the 3rd day of March, 1873, or to authorize the sale of lands valuable for mines of gold, silver, or copper. [Section 6, Id.]

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The proceedings to enter coal-lands under the above sections are further regulated by a circular of the General Land-office, dated July 31st, 1882. The proceedings are also regulated by mining laws and regulations approved June 24th, 1899; and also by instructions issued under the Act of Congress, approved May 14th, 1898, entitled "an Act extending the Homestead Laws and providing for Right of Way for Railroads in the District of Alaska and for other Purposes." The former refers chiefly to the location of mineral claims and the various notices of application, etc., and the surveying thereof, made under authority of the Surveyor-general of the State or Territory in which the claim lies; and the fees are regulated by the Commissioner of the General Land-office. The most important clause therein, referring to non-citizens, is as follows:—Section 13 of Act of May 14th, 1898, according to native-born citizens of Canada "the same mining rights and privileges" as those accorded to citizens of the United States in British Columbia and the North-west Territory by the laws of the Dominion of Canada, is not now and never has been operative, for the reason that the only mining rights and privileges granted to any person by the laws of the Dominion of Canada are those of leasing mineral-lands upon the payment of a stated royalty, and the mining laws of the United States make no provision for such leases.

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## APPENDIX B.—BRITISH COLUMBIA.

In British Columbia, coal-prospecting is regulated by the Coal-mines Act, 1897, as follows:—

### Short Title.

1. *Short Title.*—This Act may be cited as the "Coal-mines Act." C. A. 1888, chapter 83, section 1.

### Prospecting Licence.

2. *Coal-lands desired to be Acquired must be Staked before Possession taken.—What Notices of Intention to Apply for Prospecting Licence must be given.*—Any person desirous of prospecting for coal or petroleum and acquiring a lease of any lands held by the Crown for the benefit of the Province, under which coal-measures or petroleum are believed to exist, or wishing to procure a licence for the purpose of prospecting for coal or petroleum upon lands under lease from the Crown, in which the mines and minerals, and power to work, carry away, and dispose of the same, is excepted or reserved, shall, before entering into possession of the particular part of said coal-lands he or they may wish to acquire and work for coal, place at one angle or corner of the land to be applied for a stake or post, at least 4 inches square, and standing not less than 4 feet above the surface of the ground; and upon such initial post he shall inscribe his name, and the angle represented thereby, thus: "A. B.'s N.E. corner" (meaning north-east corner), or as the case may be, and shall cause a written or printed notice of his intention to apply for such a

licence to be posted on some conspicuous part of the land applied for by him, and on the Government Office of the district for thirty clear days. He shall also publish a notice of his intention to apply for such licence for thirty days in the *British Columbia Gazette*, and in some newspaper circulating in the district. 1892, chapter 31, section 2.

3. *Application for Prospecting Licence.—To be in Duplicate and Illustrated.—Fee to accompany.*—After the expiration of the thirty days' notice, and within two months from the date of its first publication in the *British Columbia Gazette*, he shall make application in writing to the Assistant Commissioner of Lands and Works for the district within which the land required is situate, for a prospecting licence over such land for any term not exceeding one year. Such application shall be in duplicate, and shall be illustrated by plans or diagrams showing approximately the position thereof, and shall give the best practicable written description of the plot of land over which the privilege is sought; and the application shall be accompanied by a fee of 50 dollars [£10] for each and every licensee. The Assistant Commissioner shall then forward one copy of the application and plan, together with the fees and his report, to the Chief Commissioner of Lands and Works, who shall, if no valid objection has been substantiated, grant to such applicant a prospecting licence as aforesaid. 1892, chapter 31, section 3.

4. *Shape of Land to be Acquired and Acreage.*—Every piece of land sought to be acquired under the provisions of this Act shall be of a rectangular shape, and each licence shall include within the general limits therein defined land not exceeding 640 acres for each licensee, and such land shall be in one block. The 640 acres shall measure 80 chains by 80 chains, and all lines shall be run true north and south, and true east and west. 1892, chapter 31, section 4.

5. *Lieutenant-governor may grant Lease to Licensee discovering Coal.—When Lessee entitled to purchase Coal-lands leased.*—It shall be lawful for the Lieutenant-governor in Council to grant a lease of lands covered by prospecting licence, for coal-mining purposes to any licensee who produces satisfactory evidence that he has discovered coal on the lands held under his licence, for a term of five years, at an annual rental of 10 cents [5d.] per acre; and if, during the term of such lease, or at the expiration of such term and within three months thereafter, the lessee can show conclusively that he has continuously and vigorously prosecuted the work of coal-mining, and has fully carried out the provisions of his lease, he shall be entitled to purchase the said lands at the rate of 5 dollars [£1] per acre, payable in full in one payment at the time of sale:

(*a.*) *Lands to be Leased must be Surveyed.*—Provided that a lease shall not be issued until after the land has been surveyed in a legal manner, and to the satisfaction of the Chief Commissioner of Lands and Works, by the applicant:

(*b.*) *Lessee to pay Royalty.*—Provided, also, that in addition to the annual rental of 10 cents [5d.] per acre, the lessee shall pay to and for the use of Her Majesty a royalty of 5 cents [2½d.] per ton upon every ton of merchantable coal and 1 cent [½d.] per barrel on all petroleum raised or gotten from the leased premises:

(*c.*) *Lease to contain certain Provisions.*—Provided, further, that the lease shall contain provisions binding the lessee to carry on coal-mining, and works incidental thereto, continuously, and to make a reasonable use, within reasonable periods, of the premises thereby granted, and to apply the same to the purposes intended, to the satisfaction of the Chief Commissioner of Lands and Works. And any such lease may be subject to any general stipulations which the Lieutenant-governor in Council may see fit to impose:

(*d.*) *As to working Coal-land in Partnership.*—Provided, also, any number of persons, not exceeding ten, uniting in partnership for the purpose of holding and working coal- or petroleum-lands which adjoin each other, and for which leases have been granted, shall be entitled to work such land as a firm, and in such case it shall not be necessary for each leasehold to be worked separately, provided work is carried on upon any one of them to the satisfaction of the Chief Commissioner of Lands and Works. 1892, chapter 31, section 5, and 1895, chapter 37, section 3.

6. *Licences to cease at the Expiration thereof.*—Every licence shall absolutely cease at the expiration thereof, and a new licence over the same land or any part thereof may be granted to any new applicant upon complying with the requirements of this Act. C. A. 1888, chapter 83, section 9.

7. *Renewal of Licence for further Period of one Year.—Fee therefor, 50 dollars* [£10].—Every applicant, upon proving to the satisfaction of such Chief Commissioner of Lands and Works or Assistant-commissioner that he has bonâ fide explored for coal during the said term of one year, shall be entitled to an extension of the said term for the second period of one year, upon payment of a further sum of 50 dollars [£10] for each and every licensee. An extension of the term for a third period of one year may be granted on like conditions and terms as the first extension:

(*a.*) *A number of Licensees may prospect as a Firm.*—Provided also, any number of licence-holders, not exceeding ten, uniting in partnership for the purpose of prospecting for coal or petroleum on lands which adjoin each other, and which are covered by the licences held by such licence-holders, shall be entitled to prospect such land as a firm; and in such case it shall not be necessary for each licence-holder to prospect separately, provided prospecting is carried on upon the land covered by one of the said licences, to the satisfaction of the Chief Commissioner of Lands and Works. C. A. 1888, chapter 83, section 10, and 1895, chapter 37, section 2.

8. *Restricts Unlimited Use of Timber, etc., by Licensee.*—Every person holding a prospecting licence may use the timber and stone on the land included in such licence for the purpose of his mining operations, and for erection of buildings on the said land, but not further or otherwise. C. A., 1888, chapter 83, section 11.

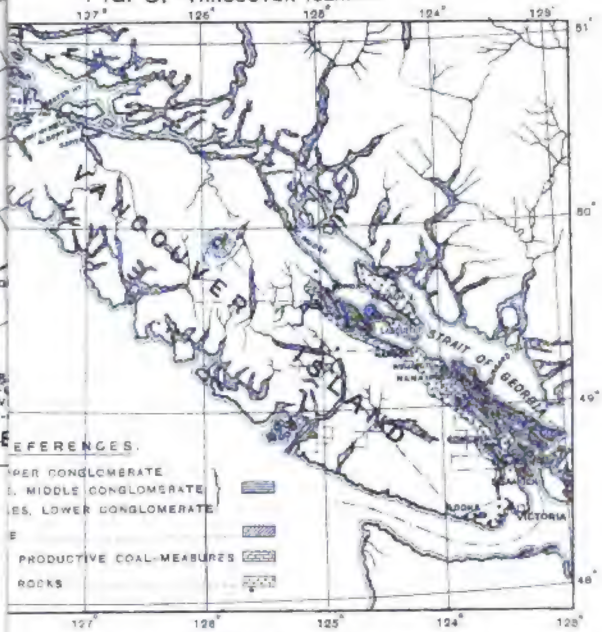
9. *Disputes as to Right to Prospecting Licences, etc., how decided.*—In case of any dispute as to the right or title to a prospecting licence or to any claim under this Act, the same shall be decided by the County Court or a Judge thereof, upon petition, in a summary way, who shall have full power to order what shall be done in the premises, and as to the costs thereof. C. A. 1888, chapter 83, section 12.

10. *Transfer of Licences.—Notice thereof to be given to Chief Commissioner of Lands and Works.*—No prospecting licence issued under this Act shall be transferred by the licensee to any other person unless a written notice to the Chief Commissioner of Lands and Works shall have been first given. C. A. 1888, chapter 83, section 13.

11. *Security to be first given.*—No coal-prospecting licence shall be issued over any Crown lands which have been leased, or in respect of which a timber-licence has been issued, unless and until due security be given, to the satisfaction of the Chief Commissioner of Lands and Works, for payment of any damage which may ensue to the leaseholder or licensee in respect of the operations to be carried on under such coal-prospecting licence. 1890, chapter 32, section 3.

12. *Licences to Prospect for Coal.*—Notwithstanding anything in any Act contained, it shall be lawful to grant licences to prospect for coal over reserved

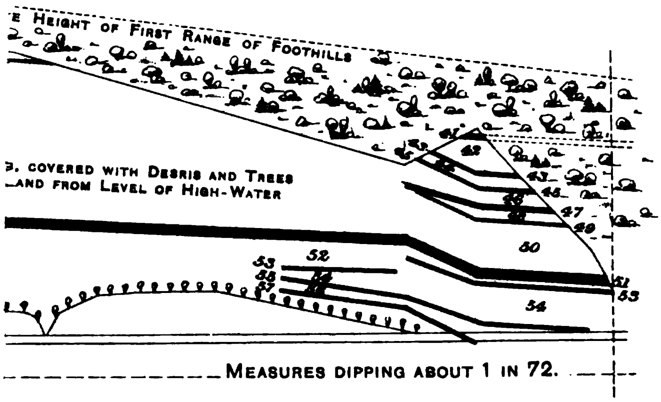

FIG. 8.—VANCOUVER ISLAND.



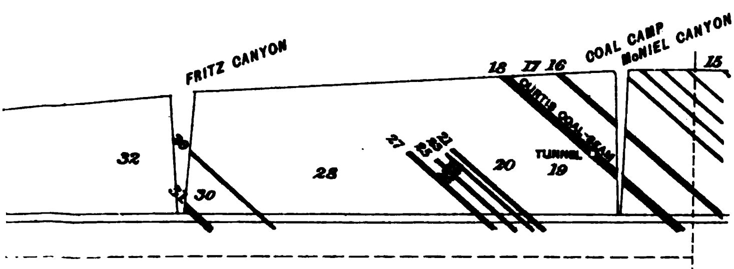

*Scale, about 76 Miles to 1 Inch.*

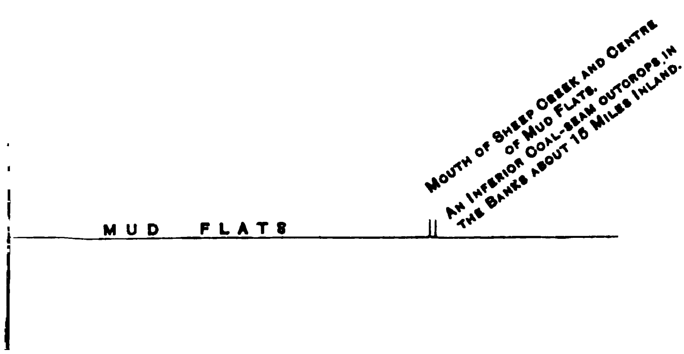
FIG. 7.—PLAN OF YAKOUN COAL-FIELD.


*Scale, about 4½ Miles or 24,000 Feet to 1 Inch.*




*· or 7,040 Feet to 1 Inch.*
*30 Feet to 1 Inch.*



lands, but such licences shall be subject to such restrictions, conditions, and regulations as may be imposed by the Lieutenant-governor in Council. 1891, chapter 15, section 16.

RIGHTS OF WAY.

13. *Proprietors of Mine may acquire certain Rights of Way over the Lands of other Persons.*—It shall be lawful for any proprietor or proprietors of a mine to acquire such a portion of any Crown lands, or lands held under pre-emption or Crown grants, lease or licence, by any person or persons, as may be necessary for affording to the proprietors of any mine communication with the sea-shore or any river, or public highway, together with a block of land not exceeding 5 acres at the terminus of such line of communication, at the sea, river, highway, or other place of shipment: provided always, that the land so acquired shall only be used for transporting, storing and shipping coal, and for receiving and transporting such materials, commodities, and persons as may be essential to the successful transaction of the business of such mine. C. A. 1888, chapter 83, section 14, and 1890, chapter 32, section 4.

14. *Conveyance of such Lands not to include Minerals.*—The conveyance of any land acquired under the provisions of the foregoing section shall not confer upon the grantee or grantees therein named the right to the ownership of any minerals thereunder except by consent of the grantor named in such conveyance. C. A. chapter 83, section 15.

15. *Compensation.*—Prior to the acquisition of such land, compensation shall be given to the person whose land shall be taken, and if the amount of such compensation and the quantity of land to be taken shall not be agreed upon between the person whose land is to be taken and the proprietors of the mine, the amount thereof shall be ascertained by arbitration in the following manner. C. A. 1888, chapter 83, section 16.

Sections 16 to 26 have not been reprinted: they relate to the conduct of the arbitration; on death of arbitrator party appointing him may appoint fresh arbitrator; appointment of umpire; in case parties cannot agree in choosing umpire, two justices to appoint; if single arbitrator die, proceedings to commence *de novo*; if one of two arbitrators fail to proceed, the other may proceed *ex parte*; on failure of arbitrators to make award, umpire to decide matters; costs in the discretion of arbitrators; submission may be made a rule of Court; award not set aside for formal defects; and witnesses may be summoned.

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The Coal-mines Regulation Act of 1888 is almost identical with the Coal-mines Regulation Act of 1887, in force in this country. It provides that every mine must be under the control and daily supervision of a manager (possessing either a certificate of competency or of service) and if any mine is worked for more than 14 days without there being such a manager, the owner or agent of such mine sh ll each be liable to a penalty not exceeding 250 dollars [£50] and to a further penalty not exceeding 50 dollars [£10] for every day during which such mine is so worked. A certificate of competency granted by a Board of Examiners in Great Britain is not taken as the equivalent of a certificate granted by the Board of Examiners in British Columbia, and such applicant, within a reasonable time, will be required to acquire his certificate by examination from the Provincial Board.

These Acts do not apply to metaliferous prospecting or mining.

Mr. ARTHUR SOPWITH (Cannock) described the paper as an exceedingly interesting addition to the *Transactions*. Since the establishment of The Institution of Mining Engineers, there had been a number of these papers read, and the result was a collection of very valuable information. There did not seem to be much inducement for mining speculation in Alaska, although one advantage would be that they would not have to pay a tax on coal. He asked the writer whether the bright coal which was found in the seams was found in similar positions, and whether there was anything special in its appearance. It was interesting to trace the formation of coal in the brown-coal district. Bright black portions were generally found in brown-coal and even lignite, and this appeared to be due to condensation of volatile matter from the seam. He understood from the paper that there was only 10 per cent. of moisture in the seams; and this appeared to be an exceedingly small amount for seams of the description named. He moved a vote of thanks to Mr. Kirsopp for his valuable paper.

Mr. JOHN NEVIN (Mirfield) wrote that Mr. Kirsopp's account of the occurrence of Tertiary coals on the Pacific coast of America was most interesting. It is disappointing to find that none of these coal-seams were of any commercial value at the present time, except the seams which had been worked for many years by the Vancouver Island collieries, and the more recently and largely developed Crows Nest coal-field, which was producing an excellent coke used in the smelters in the Kootenay district.

Mr. J. KIRSOPP said that all the thinner coal-seams, lying in the lower section of measures, were of an appearance similar to cannel coal, but much brighter and with an uniform, glossy appearance throughout. The Cooper seam comprised two distinct beds, each of about the same thickness, but the upper portion is inferior to the lower and of a duller appearance with a decided cleavage, whereas the lower portion resembled the thinner coal-seams found below, and similar changes take place more or less in all the thicker seams lying below. The coal-seams lying above the Cooper seam were of a similar or inferior quality to the upper portion of the Cooper seam, and of a dull appearance with a decided cleavage. The moisture varied slightly in the different analyses, which were set forth in his paper.

Mr. A. Lupton (Leeds), in seconding the vote of thanks, said that he rejoiced to recognize in the writer a former pupil, and was exceedingly glad to find that he was one of those who had been to foreign parts and obtained information for The Institution of Mining Engineers.

The vote of thanks was cordially adopted.

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Mr. M. Walton Brown read a paper on "Experiments with Auxiliary Ventilators."

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Mr. T. W. Benson (Newcastle-upon-Tyne) moved that the thanks of the members of The Institution of Mining Engineers be accorded to the Geological Society for the use of their rooms for the meetings; and to the Central London Railway Company for permission to inspect their power-generating station at Shepherds Bush.

Mr. J. G. Weeks seconded the motion, which was unanimously approved.

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Mr. A. Sopwith (Cannock) moved that a vote of thanks be accorded to Mr. H. C. Peake for his services in the chair.

Mr. J. S. Dixon (Bothwell) seconded the resolution, which was cordially approved.

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The meeting was then closed.

# THE GUIBAL FAN COMPARED WITH A DYNAMO.*

By ÉMILE GOSSERIES.†

On examining the chart, which gives, for an uniform velocity, the characteristic curves of the water-gauges, of the volumes and of the mechanical efficiencies of the Guibal fan, 19·68 feet (6 metres) in diameter, at the St. Théodore shaft of the Sacré-Madame colliery, it will be noted that:—(1) The volume of air produced by the fan increases almost in direct proportion to the temperament of the mine; (2) the mechanical efficiency is a maximum and is almost constant for temperaments between 2·5 and 4·5; and (3) the water-gauge is a maximum for the temperament of 2·00.‡

These results prove that:—(1) This fan should be worked on temperaments between 2·50 and 4·50, preferentially at the latter, which gives a volume equal to 1,620 cubic feet (45·84 cubic metres) per second, with the high mechanical efficiency of 63 per cent.; (2) one must not attempt to work a fan at the maximum water-gauge which it can produce. As a matter of fact, the maximum water-gauge of this fan corresponds to the low temperament of 2·00, to the diminished volume of 7,240 cubic feet (20·50 cubic metres) per minute, and the reduced mechanical efficiency of 61 per cent.

An examination of the curve of water-gauges leads to the following discovery: that, for temperaments between 2·00 and 4·00, the water-gauge decreases whenever the volume or the temperament increases. As it is precisely between these limits that the mechanical efficiency remains almost constant, one sees the advantage that there is in working the fan between these limits—that is to say, beyond the sharp bend in the curve of water-gauges, as also occurs in the case of a dynamo.

* "Quelques Considérations sur le Ventilateur Guibal comparé à une Dynamo." *Publications de la Société des Ingénieurs sortis de l'École Provinciale d'Industrie et des Mines du Hainaut*, 1901, vol. x., pages 256-265.

† Translated by Prof. Henry Louis, M.A.

‡ Plate V., *Publications de la Société des Ingénieurs sortis de l'École Provinciale d Industrie et des Mines du Hainaut*, 1896, vol. v.

If for a constant velocity the water-gauge increases, it is because the volume of air, and consequently the temperament, decreases. If, on the other hand, the former diminishes, it is because the two latter factors are increased. By simple inspection of the velocity and of the water-gauge in this portion of the characteristic curves, one can therefore immediately recognize whether the volume of air or the temperament vary, and in what direction.

There is accordingly, for a given velocity and for temperaments between 2 and 4, a definite relation between the water-gauge and the volume of air. If the water-gauge decreases, the volume inqreases, and *vice versa*. If, therefore, the volume be maintained constant, the water-gauge will also be constant. Thus, for the temperament of 3·204, at the velocity of 120 revolutions per minute, the volume will always be 1,180 cubic feet (33·43 cubic metres) per minute with a water-gauge of 4·409 inches (112 millimetres).

If by any means whatever, the volume produced by the fan is varied, at the same velocity, the water-gauge will also vary. Thus, for example, if the volume of air is caused to vary by the aid of a tube fitted with a tap, which serves as a means of communication between the inlet of the fan and the atmosphere, the water-gauge will vary in the inverse direction, and if the volume be kept constant the water-gauge will remain constant.

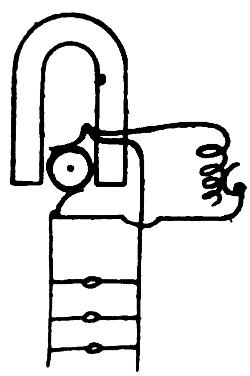


FIG. 1.

A fan thus modified would be analogous to a magneto-electric machine with a permanent magnet, having a shunt to its brushes. The tube connecting with the atmosphere is looked upon as coming from the chimney of the fan, which is the positive pole, and it opens into the inlet of the fan, or the negative pole. The tap on the tube performs the function of a rheostat.

In the magneto-electric machine, by modifying the resistance of the shunt, the potential at the poles may be kept constant, the dynamo running at a constant velocity (Fig. 1). Necessarily in this case, the electromotive force being constant, if the same potential is maintained at the poles, it is because the internal loss

is constant, and therefore the total current produced has the same value. This occurs because the combined resistance of the rheostat and of the outside circuit maintains its value or its temperament.

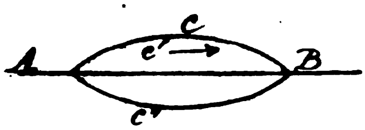



Fig. 2.

In any fan provided with a tube and a tap, having therefore a variable resistance, the causes producing the aeromotive force, such as the angular velocity, the trajectories of the lines of flow, the inclination of the edges of the blades, and the gain in water-gauge due to the chimney are invariable. This aeromotive force is therefore constant, like the electromotive force of a dynamo.

The derived current of air acts so as to keep the total output of the fan constant, and to keep the water-gauge at the inlet of the fan constant (like the difference of potential at the poles of the dynamo).

It is well known that when two or more air-currents (Fig. 2) are split at A and united again at B, the air divides itself among the different conduits, $c$, $c'$ and $c''$, in such a manner that the resistance to the movement of the air in each split shall be the same and equal to $P_A - P_B$. If this difference of potential, $P_A - P_B$, be increased, without varying the areas of the sections of $c$, $c'$ and $c''$, more air must pass through these conduits, and *vice versa.*

Fig. 3 represents the fan, and the air-currents, V, of the mine, and, $v$, of the regulating-tube join in the inlet.

The volume of air exhausted by the fan will be: $Q = v + V$. Let us suppose that the maximum water-gauge is H (Fig. 4). If by increasing the temperament, V increases and becomes V′, Q will increase, and H and $v$ will diminish. There will, therefore, be a new series of conditions in which H′ is less than H; Q′ equals $V' + v'$, and is greater than Q, which equals $V + v$; V′ is greater than V; and $v'$ is less than $v$.

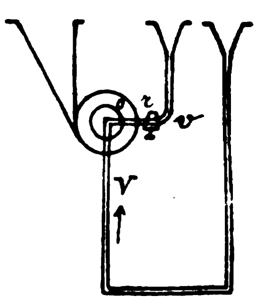



Fig. 3.

We shall then have two air-currents, V′ and $v'$, both starting from the atmosphere, and which re-unite at the inlet, O, of the fan (Fig. 3). If at this moment we increase the water-gauge, H′, by any means what-

ever, without interfering with the tap, $r$ (for instance by increasing the velocity of the fan), the two currents, $V'$ and $v'$, will increase. If $r$ be closed, without changing the velocity, $v'$ will diminish, as also will $Q'$; $H'$, however, will increase, so that when $H'$ becomes once again equal to $H$, we shall obtain $V'' + v''$ equals $Q$; $V''$ will be greater than $V'$; and $v''$ less than $v'$. This increase of $V'$ will be felt in every portion of the mine.

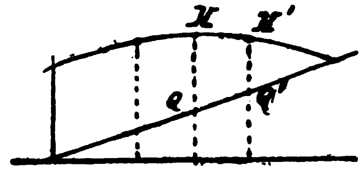


FIG. 4.

Thus the first increase of V, caused, for example, by increasing $c''$, produces a diminution of H and of $v$, and also a diminution of the volume of air in $c$ and $c'$. By closing $r$ we increase H, and consequently V, producing thus an increase of current in $c$, $c'$ and $c''$. We, therefore, have partly compensated, in $c$ and $c'$, the loss of air produced in the first place by the increase of $c''$.

Now let us suppose that V is diminished by some modification of the circuit of the mine, H maximum will diminish, $v$ will also diminish, and we shall have $Q'$ equals $V' + v'$; V will be less than $V'$; Q will be less than $Q'$; $v$ will be less than $v'$; and $H'$ will be less than H.

In order to make $Q'$ equal to Q, let us open the tap, $r$, $v'$ will then increase, $H'$ also, but $V'$ will also increase up to the instant when $H'$ becomes equal to H. We shall then have $Q''$ equal to Q and also equal to $V'' + v''$; $V''$ will be greater than $V'$; and $v''$ is greater than $v'$.

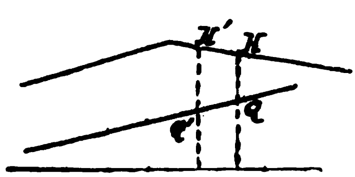


FIG. 5.

Let us take a case (Fig. 5), where the fan is working at a depression, H, beyond the maximum point of the curve of water-gauges. If V is diminished and H is increased, it is because Q is diminished, notwithstanding the increase of $v$. We shall then have $H'$ greater than H; $Q'$ is equal to $V' + v'$ and is less than Q, which equals $V + v$; $V'$ is less than V; and $v'$ is greater than $v$.

If we then close the tap, $r$, $v'$ will diminish and $Q'$ also, but $H'$ will again increase. The increase affecting the mine, $V'$ will increase, compensating for the diminution of $v'$, and the final state

of affairs will be as follows: $H''$ will be greater than $H'$, $Q''$ equals $V'' + v''$ and is less than $Q'$, which equals $V' + v'$; $v''$ is less than $v'$, and $V''$ is greater than $V'$. And if one succeeds in maintaining $H''$ equal to $H'$, it is because $V''$ would be equal to $V' + v'$; that is to say, the mine would have the benefit of the whole of the diminution of $v'$.

We may see by these examples that the maximum value of H can be obtained by means of the regulating-tube. The total temperament will always include both the mine and the regulating-tube.

To determine $V$, $V'$ and $V''$, $Q$, $Q'$ and $Q''$ have first to be obtained for the corresponding water-gauges $H$, $H'$ and $H''$, according to the characteristic curves of the fan. Next, the curve of volumes, $v$, $v'$ and $v''$, must be traced for the same water-gauges, and for definite openings of the tap, $r$. One would thus get $V$, $V'$ and $V''$ equal to $Q - v$, $Q' - v'$ and $Q'' - v''$. There would also be wanted a delicate water-gauge, so that the variations of H could be read off easily.

The advantage, which would result from such a method of regulation, would be that whenever the temperament of the mine happened to vary, this could be partly remedied without changing the opening of the sliding-shutter whilst the fan was running; and the change could be made on the Sunday following.

In case of air entering through the regulating-tube, there would be an increase of work; but it must be remembered that by increasing the water-gauge by increasing the velocity of the fan there would also be an increase of work. In the latter case, the mechanical efficiency would remain the same, but in the former, there might be an improvement in the mechanical efficiency compensating for the increase of work. This would depend upon the point of the characteristic curve at which the fan might be working.

The author considers it interesting to set forth the preceding considerations; but up to the present he has never had an opportunity, or otherwise, he would have proved experimentally the accuracy of his reasoning.

At first sight, one might doubt that there would be an advantage in increasing the water-gauge by the entrance of air from the atmosphere. The author has, however, now shown the road; and possibly some of his colleagues will take up the matter.

Prof. Macquet, the director of the School of Mines at Mons, suggests that the calculation might be made as follows:

Let there be a mine and a fan, in which the regulating-tube is closed, and they produce a volume, Q, at the maximum water-gauge, H, of the fan. The temperament of the mine is:—

$$T = \frac{Q}{\sqrt{H}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

If the temperament diminishes, the volume becomes $q$ less than Q, with $h$ less than H. The temperament will then be:—

$$t = \frac{q}{\sqrt{h}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

With the tube closed (or of infinite resistance), the mine produces the maximum volume, Q, with the maximum water-gauge, H. If the regulating-tube be opened until the apparent water-gauge has again risen to H, the total volume of air produced by the fan will resume its value, Q, and the general or combined temperament will resume the value, T.

At this moment, the tube will be passing a volume, $v$, and the mine a volume, V, and we should have:—

$$v + V = Q \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

$$\frac{v + V}{\sqrt{H}} = T \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (4)$$

If V equals $q$, there will be equality; if V is greater than $q$, there will be an advantage. The author considers that V would be greater than $q$, because $q$ corresponds to the water-gauge, $h$, while V is produced under a water-gauge, H, greater than $h$.

It is well known that when two air-currents split at any point to rejoin at another, if the difference of pressure between these two points increases, the air-current will increase in both conduits. Now, in this case, the currents start from the atmosphere and unite at the inlet of the fan.

Knowing the characteristic curves of the fan, it would be sufficient to read the water-gauge, $h$, in order to determine $q$. One would have:—

$$v = Q - V \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (5)$$

and

$$\frac{q}{\sqrt{h}} = \frac{V}{\sqrt{H}}; \text{ whence } V = \frac{q\sqrt{H}}{\sqrt{h}}; \quad . \; . \; . \quad (6)$$

and

$$v = Q - q\,\frac{\sqrt{H}}{\sqrt{h}}, \quad . \; . \; . \; . \; . \; . \; . \; . \quad (7)$$

the volume which the tube would be passing at that moment.

It would be advisable to give the engineman some easy means of controlling the volume, $v$. The tube might be furnished with an orifice in a thin plate, on which a Pitot tube might be placed. The tube would give $h$ by the formula $u = \sqrt{2gh}$. Whence, $h = u^2/2g$. If S be the area of the hole in the thin plate, S$u$ is equal to $v$, therefore, $h = v^2/S^2 2g$; and also $v = hS^2 2g$.

It would be easy to compare the value of $v$ given by this last formula with that of equation 7, by choosing a suitable value for the area, S.

Actually, $h$ in the formula is measured in feet of air-column, and it is read in inches of water-gauge, $h'$. The inches of water-gauge, $h'$, are equal to $h$ (or $h' \times 5{\cdot}2$ pounds $\div$ 0·0807 pounds) feet of air of a weight of 0·0807 pounds per cubic foot.

Consequently, $v^2 = h' \dfrac{S^2 2g\, 5{\cdot}2}{0{\cdot}0807}$. This form of formula is adopted in order that $\dfrac{S^2 2g\, 5{\cdot}2}{0{\cdot}0807}$ may be a numerical co-efficient with a simple square root. A table should be made of the values of $v$, corresponding to the values, $v = \sqrt{h}\sqrt{\dfrac{S\ 2g\ 5{\cdot}2}{0{\cdot}0807}}$, for different values of $h$; and alongside would be placed the values of the volumes, $v$, calculated by formula 7.

The first would be a table of the volumes observed indirectly by means of the water-gauge.

The working would be as follows:—The engineman having re-established the maximum water-gauge, would observe the water-gauge on the regulating-tube (this is equivalent to a voltmeter calibrated in ammeters), and take from the table the observed volume. If it is equal to the calculated volume, the diminished mine receives as much air as the old one. If $v$ is less than this volume, it is because V is greater than $q$, and there will be an advantage in working in this way. If, on the other hand, $v$ is found to be greater, the tap must be closed and the mine left with its diminished section. It would be impossible to restore V to its primitive value of Q; and in order to do this, it would be necessary that $v$ should be zero.

## THE CENTRAL LONDON RAILWAY: GENERATING STATION AT SHEPHERDS BUSH.*

Three-phase electric current is generated at a pressure of 5,000 volts, and is transmitted through four 3-core cables to step-down transformers erected in sub-stations at three points along the line, where rotary converters deliver continuous current to the third rail, from which it is collected by a slipper on the locomotive.

The first type of electric locomotives, built by the British Thomson-Houston Company, are shown in Figs. 1 to 4 (Plate XVIII.). The weight of each locomotive is about 44 tons. There are four gearless motors on each, that is, one on each axle. The weight of the frame and coils of each motor, with field-coils in place, is 8,500 pounds, making a total weight for the motor of 11,500 pounds. The driver's cab is fixed in the centre of the locomotive (Fig. 1), giving a capital look-out in whichever direction it travels. In the space over the trucks are fixed resistance-coils (Figs. 3 and 4) with a passage-way between them, the whole being protected by a sheet-iron cover. The efficiency of the motors is between 92 and 93 per cent. The temperature does not rise more than 90° Fahr. on a 2 hours' run at full load. At starting, the four motors are placed in parallel in pairs, and the two pairs in series. At the same time there is a resistance in series with them. Then graduated parts of the resistance are progressively short-circuited, until no resistance remains in use. This is the first running-position. The next move of the controller-handle cuts off the supply of power while the four motors are all put in parallel and the resistance in series with them. The resistance is progressively short-circuited until the second-running position is reached, when the full electric pressure is applied across the terminals of each motor.

The third rail, which carries the power to the locomotives' collecting-slipper, is a steel channel weighing 85 pounds per yard, supported at intervals of 7½ feet on porcelain insulators. It is worthy of note that the current-carrying capacity of this steel,

* *Trans. Inst. M.E.*, 1898, vol. xv., page 459.

which was produced by the North-Eastern Steel Company, is the highest that has ever been made. On the usual basis of comparison, this steel has less than seven times the resistance of pure copper of the same size, while the third rail more recently installed on the New York elevated railway, has eight times the resistance of pure copper; or, it is 14 per cent. more wasteful than this British-made steel as a conductor of electricity.

The track-rails are of bridge-section, weighing 100 pounds to the yard, and are laid on longitudinal sleepers, bedded in concrete. The trains run at 2½ minutes' intervals, and eventually probably at 2 minutes' intervals; and they attain an average speed of 14 miles an hour. There are thirteen stations (both terminals included) in the length of 30,489 feet between Shepherds Bush and the Bank. This gives average runs of 2,541 feet, or something less than ½ mile each. This distance is covered in about 104 seconds, to which must be added 20 seconds for the stoppage in the station, or about 2 minutes, average time, from start to start. Each train consists of seven carriages, with a total seating capacity of 336 passengers. The weight loaded is 105 tons, in addition to 44 tons for the locomotive.

The power-generating station is situated 3,000 feet beyond the western terminus, so that the current is distributed in addition to the 30,489 feet between the terminal stations, over a further length of 3,108 feet at Shepherds Bush; and at the Bank over a length of 600 feet from the platform to the end of the sidings. The total length of continuous railway over which electric traction is provided, is 34,197 feet, or 6·47 miles, exclusive of cross-over roads at stations and sidings. The tri-phase current is transmitted at a pressure of 5,000 volts, with a loss which only attains 4 per cent. at an output of 6,000 kilowatts. On the three-wire system, the loss would be 17 per cent. at this output, and there are, moreover, further losses in the three-phase system. The current is passed through step-down transformers and rotary converters, before it enters the lines as direct current at a pressure of 500 volts. In both processes, there is a loss, but it decreases (as a percentage) as the load increases, and hence the total losses are a minimum at an output between 3,000 and 4,000 kilowatts. On the contrary, the total losses with the three-wire system increase with the load.

The general arrangements of the power-generating station are shown in Figs. 5 to 7 (Plate XIX.). The boiler-house contains

16 Babcock-and-Wilcox boilers in eight batteries of two each (Fig. 5). The evaporative power of each boiler is 12,000 pounds per hour, the heating surface is 3,580 square feet, and the steam-pressure is 160 pounds per square inch. The steam and water-drums are 42 inches in diameter, 23 feet 7 inches long, with a cross-drum 24 inches in diameter and 90 inches long, to which is attached an 8 inches stop-valve. The boilers are fitted with Vicars mechanical stokers. Coals are supplied from a coal-bunker, at the top of the boiler-house, having a capacity of 1,000 tons, fed by a conveyor, driven electrically. Each pair of boilers has a separate connection to the main steam-pipe, and each engine has its own steam-pipe, all the steam-pipes in the engine-house being placed in the basement (Fig. 7). By this arrangement, no steam-pipe in the large station is more than 8 inches in diameter, except the main steam-pipe just mentioned, while at the same time any boiler can be shut off when not required. This method of arranging the steam-pipes gives elasticity in management, with the minimum number of valves.

The exhaust-pipe to the air, and the injection and discharge-pipes are placed below the engines, the injection-pipe being 20 inches in diameter, and the discharge-pipe 22 inches in diameter. An independent combined jet-condenser and air-pump located in the basement is supplied to each engine, of sufficient capacity to take the maximum quantity of steam from it. The steam-cylinder of this pump is 14 inches in diameter by 24 inches stroke; the air-pump is double-acting, with a cylinder 28 inches in diameter by 24 inches stroke, and delivers the condensed and injection-water to the top of the four Barnard cooling-towers at the end of the station (Figs. 6 and 7, Plate XIX.).

Each cooling-tower is furnished with two fans, each 10 feet in diameter, direct-coupled to a steam-engine of 35 horsepower. The towers are 14 feet 8½ inches square, and 50 feet high from the foundation to the summit. In the interior, are a number of woven wire-mats, over which the water trickles in its descent, and at the same time it is subjected to a vigorous upward current of air from the fans. The greater part of the heat is carried away by the air-current, and there is only a trifling evaporation of the water in these towers, less than 3 per cent. of what passes through.

Power is produced by six Reynolds-Corliss cross-compound

condensing engines, each coupled direct to one 850 kilowatts three-phase generator. These engines run at 94 revolutions per minute, and yield 1,300 indicated horsepower each. The cylinders are 24 inches and 46 inches in diameter by 48 inches stroke, and are capable of being run non-condensing, and either the high or the low-pressure cylinders can be run independently. The speed variations do not exceed $1\frac{3}{4}$ per cent. between minimum and maximum load. The engines consume $13\frac{1}{2}$ pounds of steam at 1,000 indicated horsepower, when run condensing with 26·5 inches of vacuum.

In a 12 hours' test run of one complete unit, including condenser, feed-pump, stoker, conveyor and fans, the full rated load was maintained with a consumption of 3·43 pounds of coal per kilowatt hour (0·386d. per kilowatt hour). For this test, Ackton Hall washed nuts were used, costing for a small quantity 21s. per ton, delivered in London. This coal in the trial evaporated 14 to $14\frac{1}{2}$ pounds from 212° Fahr., so that at this price it was an economical quality of coal to use. Two of the 16 boilers were used, but naturally had to be held back, as their capacity is in excess of the requirements of the main-engine.

Each three-phase generator field has thirty-two poles, and yields 5,000 volts with a frequency of twenty-five cycles per second. The field-magnets revolve, while the armature-coils are held in slots in the outer stationary ring. The diameter over all is 16 feet. The core of the armature is formed of laminated plates. There are ninety-six coils—that is, one per phase for each pole, and these lie in 192 slots across the armature-core. There are three types of armature-coils differing only in the shape of the part outside of the slots, so designed that they conveniently fit around each other. The coils are formed of copper wire and highly insulated. The connection of the coils is what is known as the star or Y type. The common centre starts at the earth-terminal of the armature. The field-coils are flat strip copper, 1 inch by $\frac{1}{16}$ inch, wound on edge, with intervening layers of paper, and then they are slipped over the cores. The exciting current has a pressure of 125 volts, and is led to the revolving-field through collector-rings. The efficiency of the generator is 95 per cent. at full load, 91 per cent. at half load, and the excitation is less than 12 kilowatts. The exciters for these machines are placed near the switchboard-end of the engine-room. Four

generators are sufficient for the load on the line, and there are, therefore, always two units to spare. Space is further provided in the station for two more units, in view of possible extensions of the railway.

In the switchboard, the chief feature is in the high-tension double-break switches, all contacts are mounted on ebonite pillars, and are placed at opposite sides of an insulating plate, so that the formation of an arc between the terminals is impossible. The switches are placed high up, out of reach, and are operated by a wooden rod connected to a slotted bar. When this handle is pulled, the spring is first put in tension, and then, when the end of the slot presses against the pin, the switches are pulled out, and there is a very quick break. Three of these switches, one in each phase, are operated simultaneously by one handle.

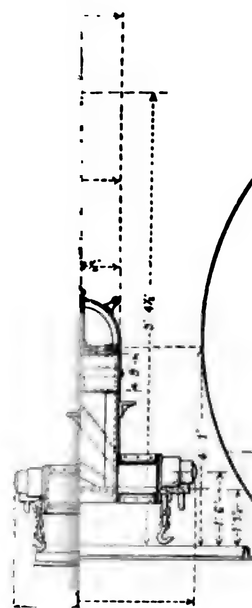
The rotary converters are of 900 kilowatts capacity, and the transformers of 300 kilowatts are connected three in delta. At Notting Hill, Marble Arch and Post Office stations, two rotary converters are employed. The rotary converters are twelve-pole, running at 250 revolutions, and capable of being started either from the three-phase or the direct-current sides. The efficiency is 95 per cent. at full load, and 93 per cent. at half load. The total weight of each rotary converter is 68,000 pounds. The three-phase current is fed from the transformers to the rotary converters at 310 volts, and the direct current is drawn from the converters at 500 volts. There are three contact-rings for the three-phase current to enter the armature, which is of the ordinary twelve-pole drum-wound variety. The armature winding is connected to the contact-rings symmetrically at one point for each phase for each pair of poles, and also to the direct-current collecting brushes as usual, one positive and one negative per pair of poles. The rotary converters are self-starting, and when in action the field is excited from the direct-current side. They experience very slight mechanical strains, as they transmit no power mechanically.

The transformers step down from 5,000 to 310 volts, and are of the air-blast type, as with enclosed sub-stations, it is necessary to arrange for the removal of the hot air from the transformers. The air is exhausted instead of being forced through, and the hot air is expelled through sheet-steel pipes running up the centre of the spiral staircase. The efficiency of each transformer is 98 per

cent. at full load, 97 per cent. at half load, and the maximum temperature rise is 70° Fahr. The weight of each transformer is 8,000 pounds.

The sub-stations are connected with the power-station by cables laid on brackets in the tunnels.

The electrical contractors' original recommendation of locomotives with springs has recently been tried, and three of these locomotives are now in service. In them, everything (except the comparatively small weight of the wheels, axles and half the motor-field) is supported by springs. The tests of Mr. Mallock of the Vibration Committee shewed that 90 per cent. of the vibration is avoided by the use of these spring-supported locomotives. Two trains of motor-carriages operated on the British Thomson-Houston Company's train-control system are also in service, and on the same authority still further reduce the vibration-trouble.



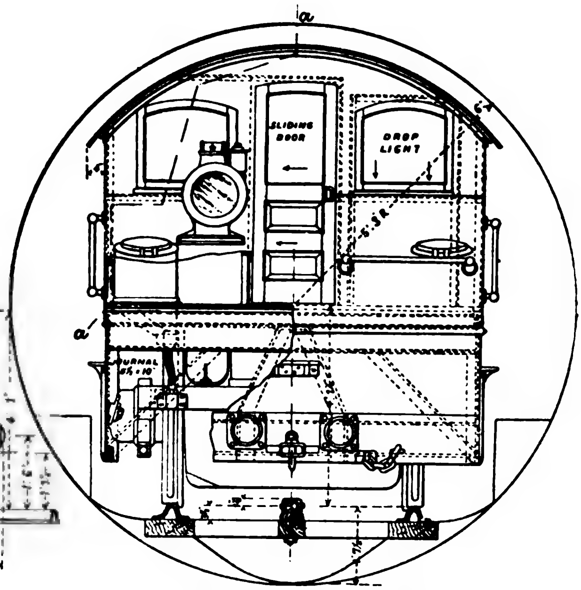
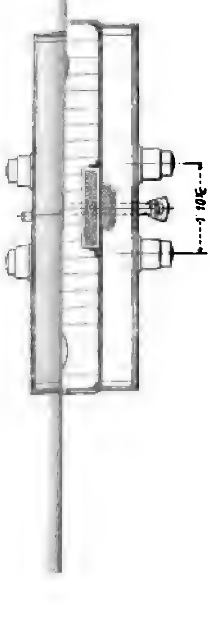



Fig. 2.—End Elevation.



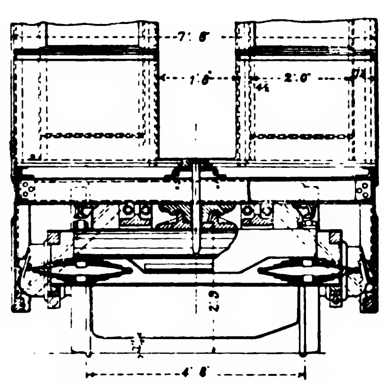


Fig. 4. Cross-section.

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Transactions, n Railway," etc. Vol. XXI., Plate XIX.

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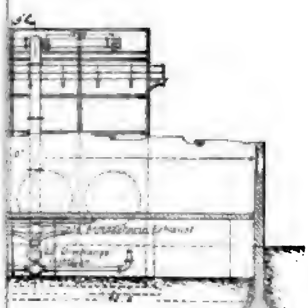
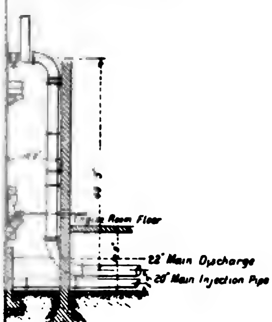


INE-HOUSE, ETC.




ROSS-SECTION THROUGH
OLING-TOWERS.

# APPENDICES.

## I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

### THE VALUE OF CHINESE MINING CONCESSIONS.

*The Value of Chinese Mining Concessions. By* JOHN A. CHURCH. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix., page* 736.

China is willing to permit foreigners to mine gold freely on the basis of a royalty amounting to 25 and 30 per cent. of the gross value, but it is rare indeed to find a mine that could support such a tax. The royalty, however, is but the beginning of expensive demands. The pay and support of officials and military men and the money composition for the thousand hindrances that can be thrown in the way are matters that can be calculated in advance, but there is another source of expense which is not susceptible of calculation, and that is the dishonesty of all hands, officials and workmen. The writer employed 800 men when mining in China, and with very few exceptions, they were as bold a body of freebooters as ever plundered the helpless. After giving an account of his experience, which would be highly amusing if it were not so hopelessly lamentable, the writer points out that mines which would yield large dividends in other countries have no chance of succeeding in China, owing to the inherent dishonesty of the people. His experience, moreover, was by no means unique. The beginning of Chinese railroads was made while he was in the country, and although the engineer in charge proposed to have the best system possible, he was obliged to abandon the block-system of running trains because the natives stole all the parts that lay above-ground. If American workmen were to be suddenly endowed with the mental characteristics of the Chinese, America, with all her resources, would be bankrupt in six months. The writer does not say that China will not improve, but it will take a long time to change the mental condition of the people, and although there are parts of China that in other hands would become important sources of gold-production, the writer does not believe that it is possible to introduce American methods there, and reap the natural profits.

X. Y. Z.

### THE FIRST INTERNATIONAL SEISMOLOGICAL CONGRESS.

*Die erste Internationale Erdbebenkonferenz zu Strassburg. By* G. GERLAND. *Petermanns Mittheilungen*, 1901, *vol. xlvii., pages* 115-119.

This Congress held its first session at Strasburg, from April 10th to 13th, 1901. It was the outcome of resolutions voted by the seventh International Geographical Congress at Berlin, in October, 1899, emphasizing the necessity of a permanent international committee for investigations regarding earthquakes.

Various proposals and communications of far-reaching interest were laid before the Strasburg Congress by seismological experts, such as a projected seismological map of the world, suggestions as to the best instruments for recording purposes, descriptions of the seismological observations made in Rumania and Norway, of the seismological services in course of establishment in France and in the Azores, and of seismological records in mines. Major F. de Montessus de Ballore pointed out that the chief problem which awaited solution was the differentiation of stable and unstable areas according to their geological constitution and geological features, and according to the geomorphogenic phenomena still taking place, or which have taken place in past geological periods.

But the main task which lay before this first Congress was the establishment of an International Seismological Association, and the drafting of statutes to that end. The states which have so far officially announced their intention to become members of this Association are Germany, Japan, Russia and Sweden. Each member-state pledges itself to communicate, through its own central office, to the central bureau of the association the results of seismological observations and experiments made within the territories of that state. Moreover each participating state is to contribute annually a sum, based on the number of its population, to the central bureau of the association. The permanent International Committee will determine the manner in which the funds thus obtained are to be expended. Provisionally the central International Bureau is located at the Imperial Seismological Observatory at Strasburg. L. L. B.

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## SEISMOLOGICAL OBSERVATORIES ON THE CONTINENT OF EUROPE.

*Über einige seismische Institute.* By DR. R. v. KÖVESLIGETHY. *Földtani Közlöny*, 1900, *vol. xxx., pages* 233-245.

Penetrated with the importance of the prompt participation of Hungary in the international chain of seismological observatories, which will shortly extend from Paris into Central Russia, and even into Bulgaria and Turkey, the Earthquake Committee sent the author on a tour of inspection of the German, Swiss and Italian observatories.

First ranks Strasburg, with its model establishment set up under the expert guidance of Dr. Gerland. Here are the headquarters of the International Seismological Association. The Basel observatory does not appear to be so well provided with modern instruments and delicate apparatus. At Milan, a few seismoscopes are to be found in the astronomical observatory; but they are barely capable of registering such shocks as occur in the plain of the Po, and are not delicate enough to record far-distant shocks. In the basement of the Palazzo Madama in Turin, hangs Dr. Agamennone's automatically-recording pendulum from a wire 75 feet long; and a well-equipped seismological observatory is kept up in the Barnabites' College at Moncalieri. The author speaks in terms of high praise of the observatory at Pavia: there, as at Rocca di Papa and Casamicciola, continuous experiments directed to the extension of seismological knowledge are systematically carried on. Signor Oddone, the director, agreed with the author in the opinion that there is some causal connexion between variation of latitude and microseismic movements; that, in fact, spontaneous movements of the earth's crust may be in part attributed to solar activity.

The observatories at Padua and Trieste are also described, and then the

author sketches rapidly the observations made on a journey through Italy in 1895 when he visited the seismological institutes of Rome, Portici, Casamicciola, Florence, etc.

In Hungary, it is proposed for the present to set up five seismological observatories: the central and most fully equipped establishment will be that of Budapest. The other localities chosen are Ó-Gyalla, Fiume, Kolozsvár and Zágráb.

The four well-equipped observatories already in existence in Austria are shortly to be increased in number to eight, without reckoning that of Laibach. L. L. B.

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## EARTHQUAKE IN ICELAND IN 1896.

*Das Erdbeben in Island im Jahre* 1896. *By* DR. TH. THORODDSEN. *Petermanns Mittheilungen*, 1901, *vol. xlvii.*, *pages* 53-56 *and plate V.* (*maps*).

In the months of August and September 1896, the southern depression of Iceland was visited by a succession of violent shocks which caused great havoc; and, but for the fact that the dwellings are largely built of timber there would have undoubtedly been a deplorable loss of life. Besides gathering information, by means of questions embodied in circular letters addressed to all the residents in the district, the author went over the whole of the area that had been affected by the earthquake in the summer of 1897.

The depression or plain is made up of the two administrative districts of Rangárvallasyssel and Árnesyssel with a total population of 11,850 persons—a relatively large number in so sparsely a populated country as Iceland. The average percentage of habitations, farm-steadings, etc., totally destroyed was 20, and scarcely a single building of any description escaped damage. Four lives were lost, and a good many persons were injured. As most of the cattle and sheep were out in the open, away from buildings, comparatively few of these were killed (9 cows and 20 sheep).

The most violent and most destructive shocks were five in number: they began in the east and travelled westward. After-shocks of gradually diminishing intensity continued for a whole year, that is, until September, 1897. The undulatory movement at its worst was such that neither men nor animals could keep their footing, but were thrown this way and that. On the tableland beyond the dislocations which bound the semicircular depression, the shocks were feeble, and indeed at many high-lying localities were not felt at all. The earthquake gave rise to several landslips, it opened up yawning fissures 7 and 9 miles in length, and caused small lakes and swamps suddenly to dry up. It had, moreover, considerable effect on the many alkaline thermal springs and solfataras of the region, inducing sudden and extensive variations in them, causing also some to stop altogether while new springs burst forth in other places.

Like many a former earthquake in this part of Iceland, the one here described appears to have been of purely tectonic origin. The southern plain or depression appears to consist of several fault-blocks, defined deep down beneath the surface by fractures transverse to the great known lines of fissure which run south-west and north-east by Hekla to Vatna Jökull. It is probable that the movements and thrusts going on between these transversely cut fault-blocks have caused the many earth-tremors recorded in this area. As the transverse fissures lie south-west of Hekla, this volcano remained quite unaffected, as on previous occasions, by the earthquake.

History records altogether 34 violent earthquakes in this southern plain, with loss of life and great damage to property. Ten of these earthquakes took place in the winter months, and 8 in each of the three other seasons of the year. The direction of travel appears to have been always the same, from east to west, and it seems permissible to infer that these shocks, recurring at more or less frequent intervals, through many centuries, are merely so many phases in the "settling down" of a highly-faulted area. L. L. B.

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## EARTH-TREMORS IN DAUPHINÉ, FRANCE.

*Nouvelles observations sismologiques faites à Grenoble. By* W. KILIAN. *Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences*, 1901, *vol. cxxxii., pages* 1242-1244.

On May 13th, 1901, 8·21½ a.m., took place one of the most considerable earth-shocks that had been recorded at Grenoble for a dozen years or more. The seismic wave travelled from south-west to north-east, but the seismographic instruments did not register any vertical oscillation. The shock was felt by several persons resident in Grenoble, and chandeliers, etc., suspended from ceilings were set in motion. The shock seems to have been more pronounced in other localities, in the department of the Drôme; thus, at Crest, houses rocked, furniture was displaced, and the town-hall bells were set ringing. At Saou, a landslip occurred destroying six houses. At Valence, a sudden and considerable rise in the air-temperature was observed at the time of the phenomenon.

The epicentrum appears to have lain on the border of the Alpine chain, in the neighbourhood of Crest and the Saou Forest *massif*: the shock travelled thence along the outer belt of the Alps, or Subalpine chain, to Grenoble. This earthquake evidently belongs to the category of tectonic earthquakes. In this connection it is interesting to note that local seismic disturbances have been of comparatively frequent occurrence in the French Alps during the last two years. Thus on March 1st, 1900, shocks were recorded at Sisteron and Digne, and on December 26th of the same year there was a violent shock at Chambéry travelling from north-east to south-west, accompanied by subterranean rumblings.

The author further gives a list of distant shocks recorded in November and December 1900, by the seismographic instruments at Grenoble, but not otherwise perceptible at that locality; and in conclusion points out that the Grenoble Seismological Observatory is the only one in France that registers regularly all earth-tremors, whether of distant or local origin. He argues in favour of a still more complete equipment of that observatory, as well as the establishment of a series of analogous recording-stations throughout the length and breadth of France. L. L. B.

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## EARTHQUAKE RECORDED BY MAGNETOMETER, 1901.

*Magnetische Warte zu Bochum. By* Lz. *Glückauf*, 1901, *vol. xxxvii., page* 79.

The earthquake which was felt at many places in southern Germany and Austro-Hungary during the night between January 9th and 10th, 1901, was also registered by the magnetograph at the Bochum observatory. As very marked curves, such as are generally produced by shocks to the compass, were obtained during considerable magnetic quietude at irregular intervals varying

from 10 minutes to several hours, Prof. Schmidt, of Stuttgart, described his record for this period as very much disturbed seismatically but not so magnetically; and there is no doubt that the observed manifestations were caused by the earthquake. J. W. P.

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## EARTHQUAKE IN SAXONY, IN JANUARY, 1901.

*Das Sächsische Schüttergebiet des Sudetischen Erdbebens vom* 10 *Januar*, 1901. *By* HERMANN CREDNER. *Berichte der mathematisch-physischen Classe der Königlichen Sächsischen Gesellschaft der Wissenschaften zu Leipzig*, 1901, *pages* 83-103 *and plate I.* (*map*).

The author deals with the Saxon portion of the area affected by the earthquake which took place in the Sudetian mountain-ranges on the morning of January 10th, 1901. It was, for Central Europe, an unusually violent earthquake, and while its epicentral area covered part of Bohemia and Silesia, it was only the extreme west-north-westerly portion of the ellipse that ranged across Saxony into the bordering Prussian provinces. The origin of the shock is being studied by Prof. Frech of Breslau and Dr. Woldřich of Prague, so that the author refrains from drawing any conclusions from the facts which he describes. He remarks that the voluntary organization of the Saxon Seismological Service worked admirably on this, as on previous occasions.

The author's map shows two belts of colouring in the Saxon area: one of these indicates the zone of comparatively violent shocks (5 to 6 in the De-Rossi scale), and the other the zone of less violent shocks (3 to 4 in the De-Rossi scale). Beyond these limits lie a number of isolated peripheral localities where shocks were observed (such as Leipzig). Indications as to time are not very exact, all the reports concurring, however, in putting it at about or shortly after 3·30 a.m. But the indications as to direction of travel of the seismic wave are on the whole remarkably concordant: it travelled from east to west and south-east to north-west. The usual thunderous subterranean rumblings were said by most observers to have been simultaneous with the earthquake, by some to have preceded it, and by very few to have followed it. In the peripheral localities these rumblings were not heard at all.

The pleistoseismic area, so far as Saxony is concerned, was the district of Southern Lausitz, with its centrally situated chief town of Zittau. In this district, two violent shocks (6 in the De-Rossi scale) were felt, which caused houses to rock, doors to rattle and fly open, pictures, etc., to fall from the walls, and so on. At Neu-Gersdorf, several wells ceased to yield water for many days, while, at Wetzwalde, a spring of muddy water welled forth. Some persons were scared out of their beds into the streets, and frightened birds fluttered and beat against the bars of their cages. The Lausitz mountains and their southern prolongation consist, apart from Palæozoic slates, of granite and the Quader and Pläner divisions of the Upper Cretaceous. The granite is separated from the great mass of the Cretaceous by the Lausitz fault, and the surface-waves of the seismic disturbance seemed to have travelled, by preference as it were, along the line of this fault from Northern Bohemia right up to Dresden, along a narrow strip of Cretaceous country wherein the shocks proved more violent than in the tectonically distinct areas which lie on either side of this strip. So it came about that in the neighbourhood of Dresden the earthquake was nearly as severely felt as in Southern Lausitz. In Dresden and its suburbs similar effects to those described above were observed. Some persons felt the oncoming of earthquake-nausea,

domestic animals and birds showed very marked signs of terror, walls and ceilings were cracked in places, and the water of the great artesian well (800 feet deep) on the Albert Platz was for half a day fouled by mud.

The earthquake was actually felt as far north as Magdeburg, but by the time the seismic wave reached Hamburg in one direction and Göttingen in the other it was only capable of measurement by micro-seismographic instruments (triple horizontal pendulum).

Premonitory shocks, etc., were observed in certain Saxon localities at 1 a.m., two and a half hours before the principal shock, and after-shocks were recorded on various days up to the morning of January 21st inclusive. L. L. B.

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## EARTHQUAKES IN THE DISTRICT OF VOGHERA, ITALY, 1901.

*Sul Terremoto Vogherese del* 23 *Gennaio* 1901. *By* M. BARATTA. *Atti della Società Toscana di Scienze Naturali, Processi Verbali*, 1901, *vol. xii., pages* 203-209.

This earthquake took place in the night of January 22nd to 23rd, 1901. It had been preceded by a period of tremors from December 20th onward, starting apparently at Melazzo and traceable as far as Alessandria in Piedmont. The author was at Voghera, and noted two distinct phases in the main earthquake: first, several short and sharp undulations travelling from north-west to south-east, and lasting about 4 seconds in all; then, after an extremely brief pause, a series of undulations of greater amplitude. He sent out circulars to the mayors in the province, and received 114 replies from 102 localities. These all agree in regarding the first phase as of greater intensity than the second; but, as in very many cases persons were suddenly roused from sleep by the earthquake, its duration appeared 50 per cent. shorter to them than to those who were wide awake. The evidence is rather conflicting as to the direction of travel of the undulations, varying from east and west to north and south. The usual preliminary rumbling was heard by many, and is compared to the sound of a cart moving over a stony road. The most recent preliminary shock had been observed on January 15th at Stradella, and some slight after-shocks are recorded. No one felt the earthquake, so far as the replies received show, at a greater distance from Voghera than Arenzano (43 miles) and Genoa (41 miles). On the other hand, it was recorded by seismographic instruments at Padua (146 miles from Voghera as the crow flies).

The author believes that the epicentrum lay in the alluvial belt between Voghera and Cervesina, and that it was propagated mainly in the direction of Western Liguria. Further, he holds that the earth-tremor recorded at Stradella on January 15th, and the preliminary tremors of the month of December, 1900, proceeded from quite other foci of seismic activity than that which gave rise to the Voghera earthquake. L. L. B.

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## EARTHQUAKE NEAR ROME, ITALY, 1901.

*Sul Terremoto del* 24 *Aprile* 1901 *nei pressi di Palombara Sabina. By* LUIGI PALAZZO. *Atti della Reale Accademia dei Lincei, series* 5, *Rendiconti*, 1901, *vol. x., pages* 351-354.

At 3·20 p.m. on April 24th, 1901, the author was standing in front of a regulating pendulum on the top storey of the Central Meteorological Office, at

Rome, when there took place successive jumps of the floor during a space of 5 or 6 seconds. He then went down to the basement with Prof. Cancani to note what the seismographic instruments there set up were registering: the total length of time during which they recorded seismic undulations did not exceed 4 minutes. This short duration of record and the particular character of the preliminary shocks led to the inference that the epicentrum was not far distant from Rome. In fact, a telegram was received next morning from the mayor of Palombara Sabina announcing that a violent earthquake had occurred there the previous afternoon, that some houses in the neighbourhood had been wrecked, others damaged, and that earth-tremors and subterranean rumblings were going on at intervals and reducing the inhabitants to a state of terror.

Prof. Cancani was sent as scientific expert and adviser: he found that though the shock had been indeed violent (6 to 7 in the Mercalli scale), at the village of Palombara, the houses had suffered little damage, their foundations resting on compact limestone-rock and the building-stone and mortar being both of first rate quality.

At Stazzano, on the other hand, a small hamlet consisting of wretched tenements built on a comparatively loose foundation (Pliocene clays and sands with a capping of volcanic ash), four or five dwellings had been utterly wrecked, and several others rendered uninhabitable. There the loss of life would have been considerable, had not such inhabitants as were not at work in the fields been alarmed by the preliminary shocks which had been noted during the preceding three days, and so they were out in the open at the moment of the earthquake. The hamlet of Cretone, though much nearer the epicentrum than Stazzano, suffered less damage, because the dwellings are better built and their foundations rest upon more solid rock. Still, the magnificent baronial castle, despite its enormously thick walls, has not escaped injury.

The most notable dynamical effects of the earthquake were observed at the sulphur-spring, $\frac{2}{3}$ mile distant from Cretone, and $3\frac{3}{4}$ miles from Palombara and Stazzano. Men and quadrupeds were thrown to the ground, great branches were torn off the trees and hurled through the air, while rumblings seemed to issue from the spring. This sulphur-spring in fact appears to have been the *locus* of the epicentrum, and there is some relationship between it and the seismic phenomena. Its waters deposit carbonate of lime, and in their passage through deep-lying limestone-rocks no doubt they gradually eat away channels and caverns in the limestone: then at a given moment, a mass of strata suddenly deprived of its support gives way, and the sudden snap causes a local or tectonic earthquake. Moreover the pent-up hydrogen sulphide (given off by the spring) doubtless played some part in the subterranean rumblings. The temperature of the spring is some 22° Fahr. higher than the mean annual temperature of the air in that neighbourhood, and it is calculated that the source of the spring can hardly lie deeper than 1,640 feet below the surface of the ground.

Despite the probably local character of this earthquake, the seismic waves were recorded as far away as Casamicciola and Padua. Slight preliminary shocks began on April 21st, and numerous after-shocks were observed until the first days of May. A more detailed account is foreshadowed by Prof. Cancani, to be published in the Bulletin of the Italian Seismological Society.

L. L. B.

## RECENT EARTHQUAKES IN SWEDEN, 1899-1901.

*Meddelanden om Jordstötar i Sverige. By* E. SVEDMARK. *Geologiska Föreningens i Stockholm Förhandlingar*, 1901, *vol. xxiii., pages* 180-184.

The first earthquake recorded in this summary took place in the morning of January 2nd, 1899, in Östergötland, and appeared to travel from north to south. It was of short duration, and had no destructive effects.

Another took place at 6·15 p.m. on February 11th, 1899, in the district of Nianfors, Gefleborg. It is described as in part an undulatory movement proceeding from north-west to south-east; doors were slammed, and persons standing up were shaken, though persons sitting down felt no vibration. The shock itself was preceded by what sounded like claps of thunder coming from the north-west, and lasting for about 3 or 4 seconds. Nianfors lies in a sandy plain, bounded on the north-west and south-east by high hills.

Two shocks were recorded in Western Bothnia in 1900; the first, on March 16th, at 12·3 p.m. was an undulatory movement lasting at most 30 seconds, and characterized by the usual subterranean rumblings. The other, on July 2nd, at 9·30 p.m. began with a curious motion as from below upward, and then travelled on as a wave from south to north. Subterranean rumblings were conspicuous both before and after the shocks. Doors, windows and walls were shaken, but the duration of the phenomenon was only 15 to 20 seconds.

Certain rumblings like thunder heard on December 27th at 11 p.m., in the parish of Gällared, Hogland, are attributed to earth-tremors.

On January 13th, 1901, about 8·45 p.m. with a clear frosty sky, an earthquake occurred in the province of Gefleborg, travelling from west to east; it lasted about 30 seconds, and seems to have extended over a wide area.

A violent shock took place in the parish of Qvilling in Östergötland, shortly after 1·30 a.m. on March 12th, 1901. It caused houses to rock, but lasted only a couple of seconds. The earthquake-sounds are described as resembling artillery fired from some distance. L. L. B.

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## THE FAULT-PLANES OF NORTH AMERICA.

*The Origin of Vein Cavities. By* FRANK L. NASON. *The Engineering and Mining Journal (New York)*, 1901, *vol. lxxi., pages* 177-179, *and* 209-210, *with* 11 *explanatory figures.*

The economic importance of a thorough understanding of the system of faulting of a country lies in the fact that it is the very foundation of the fissure- or vein-system. A true fissure, independently of its subsequent filling, is a fault-plane. In sedimentary strata, the faulting is generally visible, whilst in igneous rocks it may not be, and seldom is, apparent. Without going to extremes, a fissure practically reaches to the depth where the superincumbent pressure causes the rocks to flow or creep. Horizontally, the extent of the fissure is limited because the rigidity of the rocks is not absolute, the rocks themselves being susceptible to a certain extent of compression. There are fault-planes of great extent, such as the mother-lode of California and the London fault in Colorado, but faults having 1 mile of horizontal extension, more or less, are far more common.

In western North America, the general direction of the great fault-lines strikes north-west and south-east. In the Atlantic States, the veins, as well as the outcrops of the bedded deposits lie, generally, in a direction north-east and south-west. So strongly is this dictum grounded among many that no

vein in the east nor in the west is considered worthy of exploitation unless it conforms to these lines. Apart from this knowledge gained from limited experience the writer shows that the belief has a solid scientific basis, although, as he subsequently shows, there are fissures to be found extending in other directions for easily understood reasons. But with regard to the theory of the general system of the faulting and fissuring obtaining in North America, it is pointed out that, according to the geological evidence, the first land to appear on the North American continent was a small V-shaped body having its eastern leg parallel to the St. Lawrence river, its western leg lying west of Hudson's bay, and the point of the V occupying what is now the site of the great lakes. Flanking this V are two other areas, that now occupied by the Alleghany mountains on the east, and that occupied by the Rocky mountains on the west. The legs of the V and the flanking areas have respectively a north-east to south-west and a north-west to south-east direction. Following the development of the continent through its successive stages of emergence, it is found that the parallelism to the original V has been maintained up to the present time. Beginning at the Arctic Ocean, the trend of the Rocky mountains system is south-easterly and that of the Appalachian is south-westerly. Without going into elaborate detail, it is seen that the alignment of these mountain-systems has been along lines laid down in the dawn of the earth's existence and that during the earth's subsequent history there has been little or no deviation from those lines. The lines represent lines of least resistance, the mountain-ranges are the results of lateral compression from east to west (the compression being due to the shrinking of the earth's crust), along these lines, at right angles to the compressing forces, profound fracturing has occurred, and these lines of fracture are fissures or veins independently of the contingency as to whether many or few of them have subsequently been filled with mineralized matter. Hence it is that the eastern prospector looks for north-easterly strikes, while his western brother pins his faith to north-westerly strikes.

But since the rocks are homogeneous neither in structure nor in rigidity, and since the forces of compression may not advance in an even line, it is evident that whilst the bulk of the major fault-lines lie as shown, others must take a direction at right angles thereto. The result of the factors alluded to might conceivably be a simple shear with no vertical displacement, but as a matter of fact, this does not commonly appear, except on a small scale. That the axes of mountain-ranges are thus broken and pitched from the horizontal is patent to even a casual observer. In the Alleghany mountains, for instance, the longer and gentler slope is to the north-east; the shorter and more abrupt slope is to the south-west.

After discussing the case of minor faults, the writer states that both major and minor faults are the result of the shrinkage of the earth's crust, and both must of necessity extend to profound depths. But whilst minor faults may extend in any direction for a very limited distance, the major fault-lines are persistent and regular in direction, following mountain-axes. The writer afterwards makes some practical remarks of economic importance concerning various phenomena associated with contact-deposits, gash-veins, lenticles and impregnations. X. Y. Z.

## SPATHOSE IRON-ORE METAMORPHOSED INTO MAGNETITE BY CONTACT WITH BASALT.

*Ueber die Umwandlung von Spatheisenstein in Magneteisen durch Contakt an Basalt.* *By* K. Busz. *Centralblatt für Mineralogie, Geologie und Paläontologie*, **1901**, *vol. i., pages* **489-494**, *with a figure in the text.*

The fact announced in the title is one which, as the author points out, has already been recorded by several observers, but he appears to be the first to have made a detailed microscopic study of the phenomena. He had the opportunity last year (1900) of visiting Messrs. Krupp's Luise mine at Horhausen, in the neighbourhood of the Wiesbach valley, where several dykes of basalt break through the spathose iron-ore. These dykes vary in thickness from 8 inches to 40 inches: they are very probably apophyses from the basalt-boss of Kissemich, barely 1 mile away to the north-east. Towards the sahlbands the basalt becomes porous, the cavities being filled with a spheroidal double carbonate of iron and manganese, for which the name "manganosphaerite" is proposed. The iron-ore itself occurs in the form of veins in the Devonian strata. Its structure is mostly very coarse, and its colour a light greyish-brown. Sometimes it passes gradually into brown hæmatite. The zone altered by the basalt is generally narrow, averaging 6 to 8 inches in width: the first sign of alteration is a darkening in colour, and little by little the ore passes into a black dull compact mass next the basalt: here the ore acts strongly on the compass-needle and consists almost wholly of magnetite. This completely altered zone is rarely as much as 2 inches wide.

L. L. B.

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## STOKESITE, A NEW TIN-ORE FROM CORNWALL.

*Ueber Stokesit, ein neues Zinnmineral von Cornwall.* *By* A. Hutchinson. *Zeitschrift für Krystallographie und Mineralogie*, **1901**, *vol. xxxiv., pages* **345-352**, *with a figure in the text.*

The specimen, which appears to be an unique occurrence so far, was collected at Roscommon cliff, St. Just, and forms part of the Carne collection in the Cambridge Mineralogical Museum. It is a colourless, transparent, bipyramidal crystal about 4 inches long, and so closely resembles gypsum in appearance that it was catalogued as such. It is brittle, breaks with conchoidal fracture, is of hardness 6 and specific gravity 3·185, and gives a white streak. It consists of 43·1 per cent. of silica, 33·3 per cent. of tin dioxide, 13·45 per cent. of lime, with traces of iron peroxide and soda, and 8·6 per cent. of water. The chemical formula may be written as $H_4CaSnSi_3O_{11}$ or $CaO, SnO_2, 3SiO_2, 2H_2O$, and the mineral may be regarded as a tetrasilicate of tin and calcium. It is named "stokesite" in honour of Sir G. G. Stokes. L. L. B.

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## ORE-DEPOSITS IN THE WESTERN ERZGEBIRGE, BOHEMIA AND SAXONY.

*Die Erzlagerstätten zwischen Klingenthal und Graslitz im westlichen Erzgebirge.* *By* C. Gäbert. *Zeitschrift für praktische Geologie*, **1901**, *vol. ix., pages* **140-144**, *with a map and section in the text.*

The district dealt with in this paper lies partly in Bohemia, and partly in Saxon territory. Its chief geological feature is the great granite-*massif* of

the Eibenstock, which is surrounded north, east, and west by phyllites. On the western side, between Annathal and Bleistadt, the phyllites are seen to be underlain by mica-schists. Near Graslitz, the phyllites are seen in plan to project an easterly tongue as it were, over the granite: at the base of this tongue rise the Eibenberg and the Grünberg, in which hills the ore-deposits occur.

The strike of the rocks hereabouts is north and south, and the dip 20 to 30 degrees westward, so that the farther west one proceeds the higher are the horizons of phyllite that one encounters. Two distinct divisions are recognized in the phyllites:—a lower, consisting of quartzose and felspathic rocks, and an upper, consisting of more markedly argillaceous rocks. The latter occur nearer the hanging-wall of the ore-bearing formation, between the Grünberg and Klingenthal, while the quartz-phyllites of the more easterly Eibenberg form the transition to the lower phyllite-group, nearer the foot-wall of the ore-bearing formation.

Ores were worked in this district as far back as 1272, and the mineral industry here reached its climax in the eighteenth century. It was ruined by the Thirty Years' War (1618-1648), but dragged on a precarious existence till the beginning of the nineteenth century: and now the dawn of the twentieth century witnesses its revival. During all these years the old workings have been carefully tended, they have not been allowed to fall in or to be drowned out.

The ore-deposits of the Eibenberg are apparently interbedded with the greenish-grey quartziferous phyllites, the ores themselves occurring as impregnations in the quartz: there are said to be no less than 10 different ore-beds, separated by varying thicknesses of barren rock (80 to 800 feet). Faults have not been observed. The ores are iron-pyrites, copper-pyrites, arsenical pyrites, magnetic pyrites, galena, black zinc-blende, black and red copper-ores, and spathose iron. The author gives the following table of analyses, which were made chiefly with the view of determining the presence of particular metals:—

| No. | Copper. | Silver. | Lead. | Iron. | Sulphur. | Cobalt. | Nickel. | Zinc. | Gold. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1·40 | 0·0046 | 0·9 | — | — | 0·5 | trace | 1·36 | trace |
| 2 | 0·67 | 0·0018 | — | — | — | 0·4 | trace | — | trace |
| 3 | 6·80 | 0·0095 | trace | — | — | 0·7 | — | 0·80 | trace |
| 4 | 2·80 | 0·0160 | 18·2 | — | — | — | — | — | — |
| 5 | 3·00 | 0·0050 | — | — | 24·50 | — | — | — | trace |
| 6 | 2·50 | 0·0050 | — | — | 22·70 | — | — | — | — |
| 7 | 2·50 | 0·0050 | — | — | 27·50 | — | — | — | — |
| 8 | 3·50 | 0·0080 | — | — | 25·60 | — | — | — | — |
| 9 | 3·72 | — | — | — | — | — | — | — | — |
| 10 | 3·16 | — | — | — | — | — | — | — | — |
| 11 | 2·39 | 0·0050 | — | 37·94 | 27·97 | — | — | trace | — |
| 12 | 2·49 | 0·0250 | — | 17·38 | 5·17 | — | — | — | — |
| 13 | 15·96 | — | — | 28·15 | 23·78 | — | — | 0·52 | — |
| 14 | 14·00 | 0·0450 | — | — | — | — | — | — | — |

The ore-bodies range from 1 to several feet in thickness, they extend over a large area, and it is believed that they go down to a great depth, with a tendency to become richer rather than poorer the deeper they go. They are very sharply marked off from the phyllite country-rock: there is no gradual diminution in ore-content towards either wall. The general habit of the ores

and their gangue points to the conclusion that they occur along gliding-planes or crush-planes of the phyllites. The great abundance of tourmaline in the ore-deposits appears to indicate their genetic relationship with the intrusion of the neighbouring mass of granite. One may picture the fumaroles and ore-bearing solutions escaping from the granitic laccolite along the bedding-planes of the phyllites but following by preference the still more favourable pathways afforded by the thrust- or crush-planes. L. L. B.

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## ANTIMONY-ORES OF PŘIČOV, BOHEMIA.

*Antimonitgänge von Přičov in Böhmen.* By A. Hofmann. *Zeitschrift für praktische Geologie,* 1901, *vol. ix., pages* 94-97, *with a map and* 6 *figures in the text.*

In the granitic area of Central Bohemia, much exploration-work has been done at various times among the metalliferous veins, with the view chiefly of working them for gold and silver. Thus it came about, in the case of auriferous antimony-ore veins, that, when the gold ceased to occur in payable quantity, further operations were abandoned, the antimony-ore not being regarded as worth the trouble of working it. The progress of modern industry has changed all that, and the once-despised baser metals are now of considerable importance.

Přičov lies some 2¼ miles north-west of Selčan at the foot of Deschna Hill, which rises about 200 feet above the mine. The country-rock, largely masked by old waste-heaps, consists of a medium-grained hornblende-biotite-granite, seamed by thin dykes of kersantite. The metalliferous veins are almost exclusively associated with the last-named rock. Here, as in the neighbouring districts of Schönberg and Mileschau, a sure indicator of the metalliferous outcrops is a gossan of yellow antimony-ochre, or of white fragments of the gangue. These are particularly well seen in freshly ploughed soil, after a shower of rain.

A shaft has been sunk on the Emil vein to a depth of 200 feet, and from it workings have been carried on at five levels separated by irregular intervals. The vein strikes north and south, dips westward between 40 and 50 degrees, and varies in thickness from 4 to 20 inches. The vein-stuff, very uniform in character, consists of milk-white or bluish chert, wherein the stibnite-crystals are either irregularly scattered or distributed in stellate groups. The stibnite is reported to contain traces of gold, but not visibly in the free state. Native gold is not, however, of infrequent occurrence in association with the metalliferous veins of Schönberg and Mileschau. There the amount of gold in the quartz varies from 4 to 17·7 parts per million. The black chert of the Emil vein was found, on analysis, to contain 3·5 per cent. of antimony.

Other veins are described, such as the Irene, with a thickness of 4 to 6 inches of antimony-ore, the Deschna, which sometimes reaches the enormous thickness of 65 feet, and the Leopold.

The author does not attempt to solve the question with which he concludes his paper: what were the causes which conditioned on the one hand the formation of quartz with gold and stibnite, and on the other, the formation of chert with stibnite, barren of gold? He points out, however, that in any case the ores of Přičov, Schönberg and Mileschau are to be regarded as the product of the phenomena which attended the later phases of eruption of the granites, or perchance, of the kersantites. L. L. B.

## METALLIFEROUS DEPOSITS IN CARINTHIA.

*Zur Kenntniss der Erzvorkommen in der Umgebung von Irschen und Zwickenberg bei Oberdrauburg in Kärnten.* By RICHARD CANAVAL. *Jahrbuch des naturhistorischen Landesmuseums für Kärnten*, 1899, No. 25, 60 pages.

The south-western portion of the rectangle which comprises the district of Irschen and Zwickenberg consists of garnetiferous mica-schists and hornblende-schists, with, in many places, intrusions of the tonalite-porphyrite which forms the great mountain-mass of the Scharnik. Among these rocks lie the ore-deposits which are dealt with by the author.

Two transverse veins have been struck at Gloder farm, consisting of quartz with antimonite and pyrites: they have been shown to contain a very fair proportion of gold.

At the Fundkofel occurs a lenticular vein, with hornblende-schist as its hanging-wall, and garnetiferous mica-schist as its foot-wall, which is partly made up of schistose material and partly of quartz. The ores, which occur in it in payable quantity, are ordinary pyrites and arsenical pyrites. Two average samples yielded 46 to 48 parts of gold and 14 to 12 parts of silver per million. One sample yielded as much as 382 parts of gold and 86 parts of silver.

The ore-deposits of the Knappenstube and the Upper Dobelgraben lie among peculiarly altered hornblende-schists: they are in appearance stratified, the roof being amphibolite and the floor graphite-schists and garnetiferous mica-schists. Moreover they are traversed by cross-veins which are often metalliferous. The chief ores here are iron-pyrites, magnetic pyrites, and copper-pyrites, less abundantly arsenical pyrites, and small quantities of galena and zinc-blende. The arsenical pyrites is generally auriferous, the maximum gold-content being 104 parts per million.

In the Michel valley an apparently auriferous vein has been explored which bears galena, black blende, pyrites, and arsenical pyrites. Old workings exist in the Schwarzwald on a vein, the infilling of which is decomposed eruptive rock. The old workings at Irschen were opened up on the same strike as these and dealt seemingly with ores analogous to those of the Michel valley. There is doubtless a genetic relationship between all this group of deposits and the dyke-like mass of tonalite-porphyrite of the Scharnik. L. L. B.

## COAL IN THE LIAS OF HUNGARY.

*Kurze Mittheilung über das zwischen Vasas und Hosszú-Hetény, im Comitate Baranya befindliche Liassische Schurfterrain des Herrn Bernhard Rosenfeld in Wien.* By JOHANN BÖCKH. *Földtani Közlöny*, 1900, *vol. xxx.*, *pages* 289-295.

The author was requested by the concessionaires to visit and report on the prospects of striking the Lower Liassic coal in the area that lies between Vasas and Hosszú-Hetény, in Baranya county. Premising that the coal-bearing belt of Lower Lias, in which occur the seams of Pécs, strikes at first south-west and north-east as far as the Szabolcs colliery, but thence to Vasas the strike assumes a more easterly trend, he points out that the coal-bearing Lias is immediately underlain by the so-called "barren sandstone" of Rhaetic age, while it is overlain by younger Tertiaries (Pontic and Mediterranean series). From Vasas, the Lower Liassic belt swings round northward, a change accompanied by an increasing steepness in the dip, till it approaches the

vertical. Coal is worked in two shafts here, and farther north-east one comes to the first exploration-workings in the newly prospected area. Here an adit has been driven, about 270 feet in, and cuts across 21 coal-seams, varying in thickness from 4 to 26 inches. Certain stratigraphical considerations lead the author to suggest the putting down of a borehole or a shaft, east of Kolonie Victoria. Meanwhile some distance north-east of the adit just mentioned on the road to Hosszú-Hetény, there is No. 1 shaft some 55 feet deep and full of water: the shales on the waste-heap appear to belong to an horizon of the Lower Lias which is really above the coal-bearing strata.

On the whole, the author concludes that in regard to the search for coal the western portion of the Hosszú-Hetény area is especially deserving of attention. In fact the lie of the anticlinal is such that coal may be looked for even to the west of that, beyond the supposed limits of the coal-bearing area. It may be mentioned that trachydoleritic and phonolitic eruptives play a by no means inconsiderable part in the geology of the district. L. L. B.

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## ORE-DEPOSITS OF DOBSCHAU, HUNGARY.

*Geognostische Schilderung der Lagerstätten-Verhältnisse von Dobschau in Ungarn. By* FRIEDRICH W. VOIT. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, **1900**, *vol. L., pages* 695-727, *with* 1 *plate and* 2 *figures in the text.*

The bibliography which forms the preamble of this exhaustive memoir shows that the spathose iron-, cobalt-, and nickel-ores of Dobschau have attracted the attention of scientific men throughout the whole course of the nineteenth century, from 1798 onwards, and yet no monograph on the subject had until now been given to the world. Between 1860 and 1880, the cobalt- and nickel-production of that district was the most considerable in Europe, but various causes, and not least among them the discovery of richer deposits in other continents, have combined to extinguish a once prosperous industry.

Dobschau lies in a sort of basin, 1,475 feet above sea-level, surrounded on all sides by mountains over 3,000 feet above sea-level. The rocks of the immediate neighbourhood are mainly Devonian slates, amid which is intruded an irregular mass of diorite: on the south appears too a small serpentine-massif, separated from the diorite by a narrow strip of slates. Above the Devonian come the Carboniferous black shales, limestones and conglomerates, and Quaternary loams, gravels, etc. The metalliferous ores occur along the northern and southern diorite-slate boundary, in the form of veins which frequently at the outcrop broaden out enormously so that chalybite is got in great opencast workings. In one of the basin-shaped depressions of the diorite is a great mass of ironstone, in part overlain by Carboniferous rocks.

The sedimentary strata are described in detail, and then the eruptive rocks. Here it may be observed that the serpentine contains so large a proportion of magnetite that in some specimens that mineral forms nodules in the rock.

From the description of the ore-deposits we learn that the most interesting ore (from the industrial point of view) is a finely crystalline, compact, greyish to black earthy substance which, on an average of 18 analyses, contains 17·45 per cent. of nickel and 6·47 per cent. of cobalt. Some of the ore is traversed by fissures, with shiny graphitic surfaces: such samples are always regarded as the richest. The veins vary in thickness from that of a man's finger to 10 feet, and they frequently pinch out for some distance. In depth,

all the veins seem to converge and to diminish concurrently in thickness, some disappearing completely at the depth of 590 to 650 feet. The vein-minerals, both primary and secondary, are enumerated and described, and the author then gives an account of the massif of spathose iron-ore and ankerite, some 100 feet thick, which rests upon the diorite.

The author concludes that all the Dobschau ore-deposits owe their origin to the same series of events and are of post-Palæozoic age. Those which are in the form of veins owe their origin to the circulation of metalliferous thermal solutions through fissures torn in the rocks; and those which are in the form of *massifs*, etc., are metasomatic in nature, but are genetically connected with the fissures. L. L. B.

## INDUSTRIALLY IMPORTANT ROCKS OF COUNTY NYITRA, HUNGARY.

*Über die industriell wichtigeren Gesteine des Comitates Nyitra.* By Dr. FRANZ SCHAFARZIK. *Jahresbericht der Königlichen Ungarischen Geologischen Anstalt für* 1898 [1901], *pages* 257-276.

The author points out that there are several varieties of Permian quartzite, at present quarried only for road-metal, which could be made available in the manufacture of glass. These occur in the neighbourhood of Béd, Alsó-Elefánt, Családka, Kovarcz, Szolcsány, Végh-Vezekény, etc. The quartzite of Szulócz is so highly micaceous that the report thereon is not quite so hopeful, but the stone would make very good fireproof walls.

In the district of Kolos-Hradistye occurs a fine black marble streaked with veins of snowy white calcspar. It is easy to work and takes a good polish, but is not so well known among architects as it deserves to be. White marble is found round about Jeskófalu, and is on the whole very beautiful, but its commercial value is diminished by the frequent occurrence in it of ferruginous spots and veins. In parts it is highly translucent, and would make very good material for small statuary and mosaic. The spotty flesh-pink crinoidal marble of Janófalu is not a promising rock from the industrial point of view.

The best building-stones are the greenish-grey granite of the Zobor Hill, the brownish Eocene conglomerate of Bajmócz, the pale grey limestone and dolomite-conglomerate of Jókeö, the yellowish-white Pontic sandstones of Banka, and the pinkish Pliocene freshwater limestones of Szádok.

This paper is followed by a complete official catalogue, compiled by the same author, of all the known occurrences in Hungary of quartz and quartz-sand that could be utilized in the manufacture of glass.* L. L. B.

## BORINGS FOR PETROLEUM IN THE ZSIBÓ-SZAMOS-UDVARHELY DISTRICT, HUNGARY.

*Resultat der Bohrungen auf Petroleum bei Zsibó-Szamos-Udvarhely.* By L. ROTH v. TELEGD. *Földtani Közlöny*, 1900, *vol. xxx.*, *pages* 246-251.

As an officer of the Hungarian Geological Survey the author had mapped the petroliferous deposits of the neighbourhood of Zsibó, in the county of Szilógy; and he had come to the conclusion that it would be well to test the extension of these deposits between Zsibó and Szamos-Udvarhely. Reasoning from the known strike and lie of the rocks, from the bituminous character of

* *Tom. cit.*, pages 277-280.

their outcrops, and from the proved occurrence of petroleum in small quantities, he indicated three different points as the most likely localities for exploratory borings through the main mass of the Lower Eocene strata. The work was undertaken with the help of a State subvention, by the Bihar-Szilógy Oil-industry Company, Limited. The first boring, north-west of the ozokerite factory-village of Zsibó was begun in the Vörös Völogy or Red valley, on August 8th, 1895, and on November 15th reached a depth of 984 feet. The strata were mainly red and mottled red-and-blue clays, with intercalated beds of sandstone, and calcareous and marly concretions. Their Eocene age was proved by the occurrence of *Nummulites*. No traces of natural gas or oil were met with below the depth of 118 feet. This being so, a second boring was started on December 18th, 1895, in the Bursa valley, north-west of the first locality, and on February 29th, 1896, it was stopped short in the crystalline schists (garnetiferous and pyritiferous mica-schists) at a depth of 708 feet. Down to the depth of 658 feet, the strata passed through did not differ essentially from those described in the first boring. Traces of bitumen and ozokerite occurred at various depths between 8 and 78 feet; between 157 and 229 feet thin veins of bitumen and traces of natural gas were found in the coarse sandstone; and again in coarse sandstone, between the depths of 508 and 525 feet there was a strong blower of gas, but no oil. Thence downward no other hopeful signs were met with.

Despite the disappointing results of these two borings great expectations were formed of the third, which was so put down as to strike the anticlinal axis, along which petroleum, when present, usually wells out. This boring was regarded as decisive for the whole area between Zsibó and Szamos-Udvarhely. It was begun on April 28th, 1896, and was continued till September 30th, 1897, when at a depth of 2,644 feet below ground, 184 feet of crystalline schists had been gone through. The first strata passed through consisted of 36 feet of loams and river-gravels; below these came 2,400 feet or so of Eocene red sandy clays with a few intercalated sandstones. Natural gas was met with at various depths between 680 and 2,045 feet from the surface.

These borings are in so far useful, in the author's opinion, as the publication of the results will prevent the fruitless squandering of capital on the opening-up of deposits which do not contain oil in payable quantities.

L. L. B.

## PETROLEUM-BEARING BEDS OF LUH, HUNGARY.

*Die geologischen Verhältnisse des Petroleumvorkommens in der Gegend von Luh im Ungthale.* By ALEXANDER GESELL. *Mittheilungen aus dem Jahrbuche der Königlichen Ungarischen Geologischen Anstalt*, 1900, *vol. xii., pages* 321-335, *with* 1 *plate and* 2 *sections in the text.*

Attention was first drawn to the petroleum-springs of Luh, in the Ung valley, in 1869, and from 1870 to 1874 a certain amount of oil was got from shafts put down in the neighbourhood. It proved to be, in quality, fully equal to the best American petroleum. The great financial crisis which swept over the Dual monarchy in the last-mentioned year stopped further enterprise in the direction of boring for oil at Luh, until in 1881 a company obtained a 20 years' lease from the government, and operations were immediately started with American boring-apparatus. In the spring of 1882, it was announced that the boring-tools had suddenly broken down at a depth of 1,640 feet, and the lease was given up on the plea that at so great a depth the possible output

would not cover the expense of working. Out of seven shafts originally put down in the district, six have now crumbled in.

Luh is 1,440 feet above sea-level, and is situated very near the Galician border among the Carpathian mountains. The strata of the immediate neighbourhood are of early Tertiary age: the high ridges being made up of the coarse-grained Mogura Sandstones (Upper Oligocene), while below these come the oil-bearing Lower Oligocene and Eocene rocks. The succession of these is as follows:—sandstones; red micaceous clay-slates; black shales; thinly-bedded, fine-grained, bluish petroleum-bearing sandstones, alternating with clay-slates, and highly micaceous sandstones; and finally massive compact sandstones. Broadly speaking, the rocks are folded in a great syncline, the axis of which runs north-west and south-east. The direction of strike of the Luh petroliferous beds coincides, or is parallel, with that of the oil-bearing rocks of Galicia: moreover, the oil and the beds in which it is found exhibit the same characteristics in the Luh district as in Galicia. The practical disadvantage which attends boring for oil on the Hungarian side of the border is the great depth down to which it will be necessary to go before striking a payable oil-reservoir; namely, anything between 1,300 and 2,000 feet. This is conditioned by the steep folding and faulting of the beds: but at the depths named it is reckoned that the rocks approach more nearly a horizontal position.

The great spread of petroleum-bearing rocks in the neighbourhood, the undoubted presence of oil (crude oil struck at a depth of 1,017 feet showed a specific gravity of 0·84 at 68° Fahr.) in some localities and traces of its presence in others lead the author to conclude that it will be found in workable quantities in the upper portion of Ung county, and he believes that it is destined in time to drive foreign oils off the markets of Hungary. He points out that in the Luh district the recorded dips indicate anticlines at several localities, and it is precisely along these anticlines that the borings of oil on the Galician side of the Carpathians were attended with success, at least in most cases. He has traced the probable strike of oil-bearing beds in the upper portion of the Lubyna valley, nearly all along the Verhovina-Bisztra valley, and also in the Szuha and Ticha valleys.

The paper is accompanied by a chronologically arranged summary of the literature of the subject. L. L. B.

## SEARCH FOR PETROLEUM IN COUNTY ZEMPLÉN, HUNGARY.

*Geologische Aufnamen im Interesse von Petroleum-Schürfungen im nördlichen Teile des Comitates Zemplén in Ungarn. By* KOLOMAN V. ADDA. *Mittheilungen aus dem Jahrbuche der Königlichen Ungarischen Geologischen Anstalt,* 1900, *vol. xii., pages* 263-319, *and* 1 *plate.*

This elaborate memoir is the result of the researches made by the author in the northern part of County Zemplén, under the instructions of the Hungarian government. First of all, he gives a bibliography of the literature, extending from 1859 to 1898.

He then describes the district of Kriva-Olyka, which forms the southern slope of the Beskide mountain-range, near the Galician border. Apart from the drift-gravels and recent alluvial deposits, the strata are all of Eocene age, and are divisible into three groups: Lower, Middle and Upper. The petroleum-bearing beds do not come to the surface in this area, and they lie just below the Middle Eocene: this lower group consists largely of red, blue and green-mottled shales and micaceous bluish-green sandstones. North of

Radvány railway-station, traces of petroleum have been observed in the rocks. Great stress is laid on the repeated evidence of anticlinal folding of the strata, and of the probable occurrence of oil along these anticlines. In fact, a bore-hole put down in 1897 was carried to a depth of 712 feet (when it had to be stopped because it had been started with too small a diameter) and struck oil on one of these anticlines. The crude oil from this boring at a temperature of 66° Fahr. has a specific gravity of 0·801; its odour is not unpleasant, it is transparent, of a brownish-red hue by transmitted light, greenish by reflected light, and flows easily. Another bore-hole reached a depth of 1,020 feet from the surface, but though it disclosed strong blowers of natural gas, no oil was struck. The author recommends further boring-operations at a point west of the lower portion of the village of Kriva-Olyka. As the Middle Eocene group is enormously thick, and the strata dip very steeply, he recommends that the new boring be carried down to a depth of 1,970 feet at least. He is very hopeful of the occurrence of petroleum in workable quantities, and remarks on the similarity of the geological conditions to those prevailing in the Galician oil-fields.

The writer made careful investigations in the districts of Habura and Mikova, and dismisses the former as unlikely ever to yield oil in payable quantity. The Mikova district contains a great series of folded Eocene rocks, the lower group of which looks promising for the oil-prospector. The area within which it appears advisable to put down borings is, however, comparatively restricted, as so much of the Eocene hereabouts is overlain by a vast thickness of Oligocene beds. In consequence of the steep dip, the author considers that a single boring would not be sufficient to prove or disprove the presence of payable oil, and he recommends that three borings be put down north-east of the village of Mikova to a depth of 2,000 or 2,300 feet. He has seen petroleum oozing out from the rocks in two old abandoned shafts on the left bank of the Ripňe, in the line of the proposed borings. L. L. B.

## BORING FOR PETROLEUM IN MORAVIA.

*Ueber eine Bohrung in den Neogenschichten bei Göding in Mähren. By* Dr. E. TIETZE. *Verhandlungen der Kaiserlich-Königlichen Geologischen Reichsanstalt*, 1901, *pages* 43-49.

Traces of petroleum had been observed for about 4,000 feet on the western bank of the March, between Göding and Nimmersatt farm: whenever in that area the sand of the river-bed was stirred by a pole or churned up by a rudder, certain quantities of natural oil were observed to rise to the surface of the water, sometimes but by no means always accompanied by bubbles of gas. The latter is probably marsh-gas which would be naturally set free from the river-bed under the circumstances mentioned.

Similar observations, it may be here remarked, have recently given rise to a search for workable petroleum-deposits in other parts of Moravia (as, for instance, at Bohuslawitz in the Vlara Pass), the result of which has not yet been reported.

The outcome of the investigations made by the author in the neighbourhood of Göding is not very promising. A bore-hole in the immediate vicinity of the river-bank was carried down to a depth of 712 feet, and, passing through a succession of sands and clays, struck at the depth of 233 feet a seam of brown coal, 47 inches thick. Then came more sands and clays, till at the depth of

403 feet another seam of brown coal was struck, about 12 inches thick. This was followed by a mass of sand, 131 feet in thickness, whence escaped combustible gases, and in it occurred too some feeble traces of petroleum. Similarly feeble traces of petroleum had been met with at a depth of only 30 feet from the surface. Another succession of sands and clays brings us to the bottom of the boring, so far as it was carried down; the last traces of petroleum were observed between the depths of 630 and 666 feet below ground, and these were the strongest of any met with so far.

The author discusses the evidence for the age of the deposits afforded by the fossils which were found in the boring, and points out that in strata of such late Neogene age as these no petroleum has hitherto been recorded, at least within the limits of the Austrian empire. It is true that petroleum does occur in strata of similar age in Rumania. The nearly horizontal lie of the rocks at Göding is another point which tells against the occurrence of a natural reservoir of oil. Below the strata which have been proved doubtless occur the Carpathian (Eocene) Sandstones: the observed traces of oil may have arisen from these, so it is just possible that petroleum will some day be found in workable quantity in the Göding district, if borings are put down to depths of not less than 1,900 feet. But the author admits that in the present state of knowledge these borings would have to be put down in a rather haphazard fashion.

It is a striking fact that the petroleum-belts of Eastern and Central Galicia do not appear to have any proper westerly continuation, despite the uninterrupted prolongation of the Carpathian Sandstones into Moravia.

L. L. B.

## ALPINE GRAPHITE-DEPOSITS.

*Alpine Graphitlagerstätten. By* ERNST WEINSCHENK. *Abhandlungen der Mathematisch-Physikalischen Classe der Königlich Bayerischen Akademie der Wissenschaften*, 1901, *vol. xxi., pages* 231-278, *with* 3 *figures in the text, and* 2 *plates.*

Graphite-bearing schists are of widespread occurrence in the Central Alps, but they are rarely rich enough in that mineral to constitute deposits of industrial importance. Such deposits are rather to be found in the eastern and western spurs of the Alpine range, although perhaps the occurrences in the Monte Rosa area, more especially in the Anthrona valley, may rank as an exception. All these deposits are so similar from the geological point of view that they may be safely regarded as belonging to one and the same type, a type not confined to the Alps, but occurring as far west as Brazil and as far east as the Caucasus.

*Styria.*—The author describes in the first place the graphite-deposits of the Rottenmanner Tauern in Styria, where a belt of black chloritoid-schists with intercalated graphite-seams ranges from the Oberennsthal, along the Palten and Liesing valley as far as the Semmering. The chloritoids alternate with phyllites of varying character, and with thinner bands of chlorite-schist and limestone. Among these rocks plants of Upper Coal-measure age have been found by more than one investigator (in the chloritoid-schists immediately neighbouring a graphite-seam). The massive limestones shown in the Schwarzenbach and Leims sections have been assigned to the Silurian system, but the author regards them as more probably Permian: they overlie the graphite-bearing Carboniferous complex quite naturally, and there is not the slightest evidence of overthrust.

The graphite, which is of a high degree of purity and very suitable for the manufacture of crucibles, etc., occurs in two distinct forms, both so very compact that the characteristic bright streak is often wanting: (1) as a soft dull earthy mass, and (2) a substance practically indistinguishable from anthracite, and only differentiated from it on very minute examination. A third variety is mentioned, a sort of graphitic coke, the cavities of which are loosely filled with very pure earthy graphite, which easily falls out, and then reveals the slaggy structure of the mass. Now, it may be observed that the earthy graphite occurs where the rocks have been greatly disturbed, while the hard anthracitic variety is found associated with less highly dislocated rocks (as, for example, the plant-bearing beds); hence the inference may be drawn that the former variety is merely the crushed and pulverized representative of the latter, and that the latter was originally part and parcel of a true coal-seam.

*Piedmont.*—Through various stages of decomposition the chloritoid-schists gradually pass into pure talc-schists, a statement which applies equally to the schists associated with the graphite-deposits of the Waldensian valleys (Pinerolo). At this locality in the south-eastern portion of the Cottian Alps not far from Turin, graphite is very actively mined. The same varieties occur there as in Styria, and the origin of the deposits is undoubtedly similar, although the rocks among which they occur are different, being mainly pale gneisses showing frequently augen-structure. No plant-remains have been found here, nevertheless the author has reason to believe that the Pinerolo graphites also are metamorphosed coal-seams of Carboniferous age.

*Genoa.*—With regard to the very extensive graphite-deposits which occur in the so-called Ligurian Appennine, especially in the valley of the Bormida near Bagnasco, these are directly associated with sandstones and conglomerates, among which are interbedded fairly considerable anthracite-seams. Although the rocks here are unfossiliferous, geologists concur in regarding them as of Permo-Carboniferous age: as the rocks approach the neighbourhood of the "gneiss" they pass into phyllites, and simultaneously the anthracites gradually pass into graphite.

The author enters fully into the petrography of the subject, and then points out that what differentiates the Alpine type from many other types of graphite-deposits is that the carbon which has there assumed the form of graphite is a primary rock-constituent and of undoubted organic origin. The Carboniferous complex of the Alps owes its crystalline character to the phenomena of contact-metamorphism, induced by the granitic magma which formed the central granite-massif. It is not assumed that the coal was transformed slowly into graphite, stage by stage, but that the process was quickened by the high temperature of the igneous magma and the chemical action of the constituents separated off from it during crystallization.

In an appendix, the author deals with the relationship between the talc-schists and the graphite-schists. The former also are of economic importance, on account of their great purity, and are worked in Styria, chiefly for the purposes of glass-manufacture. L. L. B.

## PYRITES-MINES OF OEBLARN, UPPER STYRIA.

*Ueber den Kiesbergbau bei Oeblarn in Obersteiermark. By* DR. — SÖHLE. *Zeitschrift für Praktische Geologie,* **1901**, *vol. ix., page* **296.**

South-east of Oeblarn, two deposits of copper- and iron-pyrites occur among the micaceous clay-slates which thereabouts strike east and west, and dip about 35 degrees northward. Mining-operations were carried on in this dis-

trict as long as two centuries ago, but had been suspended for a considerable period, and have been recently restarted.

The iron-pyrites, which forms by far the largest proportion of the output, is used for the manufacture of sulphuric acid. It is finely crystalline, and at many places magnetic pyrites and copper pyrites are found in association with it, also at one point galena. The two last-named ores are accompanied by a quartzose gangue, some calcspar, gypsum of secondary origin (along clefts and fissures) with an undercrust of brown iron-ore.

The so-called Walchen vein is the highest and northernmost of the two deposits, while the Segen Gottes vein lies lower and more to the south. The first-named alone is being worked at present: its thickness averages about 6 feet, and there are no disturbances of any importance. The ore-body is sharply marked off from the micaceous clay-slates, the salband in places consisting of a light-coloured sericitic rock impregnated with pyrites. The workings are carried on underground in a drift about 170 feet above the level of the adit-opening and 1,300 feet distant from it: the intervening ground has been exhausted, having been worked in former times for copper-pyrites.

It is still a matter for investigation whether these Oeblarn deposits belong to the same geological horizon as those of Mitterberg and Kullwang.

L. L. B.

## AGE OF THE COAL-SEAMS OF SOUTHERN STYRIA.

*Das Alter der Kohlenablagerungen östlich und westlich von Rötschach in Südsteiermark. By* DR. KARL A. REDLICH. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, **1900**, *vol. l., pages* 409-418, *with a section in the text.*

The paper is prefaced by an elaborate bibliography of the subject, the reason for which will be understood when we realize that the age of these Styrian coal-deposits has been a matter of dispute for well nigh half-a-century.

East and west of Rötschach lie numerous isolated masses of Hippurite-limestone with which is associated the coal, sometimes in natural stratigraphical sequence, sometimes not. Around St. Agnes, the succession is in ascending order: Triassic dolomite, Gosau marls with fragmentary coal-bands, and Hippurite-limestone. Here the coal (which is always below the limestone) is undoubtedly of Cretaceous age. But a second horizon of coal lies above the Cretaceous limestones: east of Radldorf there is a succession of marly limestones, sandstones and marls with conglomerates (largely made up of Triassic dolomite and Cretaceous limestone), followed by coarse conglomerates (with Nummulitic limestone-pebbles), shales and sandstones. In the immediate roof of the coal occurs a fauna and flora of Oligocene age—this coal-horizon dates therefore from early Tertiary times. East of Wretschnigg, on the right bank of the Drave, the palæontological, as well as the stratigraphical, evidence shows that both Cretaceous and Oligocene coal-seams occur. In the neighbourhood of Stranitzen, the Oligocene lies in a basin overlying the Hippurite-limestone, and the Tertiary succession in ascending order is:—flaggy marly limestones, coal-seams, alternating with bituminous measures, bituminous marls, yellowish-brown sandy marls, and, finally, conglomerates, with Nummulitic limestone-pebbles. The fossils collected near the floor of the seams prove their Oligocene age, and the same statement holds good of the small (worked-out) coal-field east of Lemesch. There are, moreover, some fragmentary coal-deposits of still younger age in the neighbourhood of Gabrowle, south-east of Radldorf.

L. L. B.

## MINERAL RESOURCES OF TRANSYLVANIA.

(1) *Bericht über die im Herbst* 1899 *gemeinsam unternommene geologische Rekognoszierungsreise in Siebenbürgen. By* K. ŒBBEKE *and* M. BLANCKENHORN. *Verhandlungen und Mittheilungen des Siebenbürgischen Vereins für Naturwissenschaften zu Hermannstadt*, 1900, *vol. l.*, *pages* 1-42.

The authors journeyed through Transylvania in the autumn of 1899 for the purpose of examining any mineral deposits that were, or might prove to be. of industrial importance. The chief results of their observations may be summarized as follows:—

*Coal* occurs in South-western Transylvania in the Upper Cretaceous, Oligocene and Miocene formations.

The Upper Cretaceous coal in the valley of the Silberbach, near the village of Michelsberg, occurs in irregular, discontinuous masses amid a complex of grey, micaceous, shaly sandstones, and blue clays or marls. Sometimes, a ferruginous limestone, blackened by carbonaceous particles, is associated with these. The coal is got in lumps about as big as a man's fist, is of good quality, bituminous, and leaves on ignition only about 3½ per cent. of ash. Trial-workings were started at several points in the valley, but were ultimately abandoned, as the very irregular occurrence of the coal gives no hope of successful mining-operations on a large scale. It is useful locally for small country smithies.

Coal of the same age occurs in Western Transylvania, in the Marosthal at Mühlbach, and in the frontier mountain-range at Barod, and is worked at the last-named locality. At Mühlbach, the micaceous coarse-grained sandstones strikingly resemble those of the true Coal-measures. Here the coal occurs in irregular layers, from ½ inch to 6 inches thick, and from 3 to 100 feet long, slightly inclined to the bedding-planes [of the containing rock]. The thickest portions of the coal belong to carbonized fossil tree-trunks (sometimes these trees have been entirely altered into carbonaceous brown ironstone), which are scattered irregularly, but on the whole fairly parallel with the bedding, through the clays and sandstones. The mineral is a good bituminous coal, and yields on an average 3¼ per cent. of ash. Here again mining-operations on a large scale are out of the question, but the neighbouring villagers might find it profitable to work the coal for their own use. At Barod, there is a workable seam of coal in a complex of freshwater carbonaceous shales and marly limestones. The authors supply no economic details regarding this seam.

The most important occurrence of coal in Transylvania is that of the Zsily or Schyl valley, towards the Rumanian frontier. Here a series of mines, served by a light railway terminating at Lupeni, are worked by two large companies. The field is formed by a trough-like basin of Tertiary sedimentaries surrounded on all sides by crystalline schists. Three distinct groups are recognized in the Tertiary formation here, the middle one of which contains the coal-seams, associated with Oligocene brackish-water fossils. This coal-bearing group is about 1,100 feet thick and consists of alternating beds of sandstone and shale, the latter sometimes containing calcareous nodules. Among these lie bituminous marly shales and a vast number of coal-seams, 14 of which are of industrial importance. The main seam is among the lowest of all (third from the bottom), and has the enormous thickness of 100 to 240 feet. It yields only 2·8 per cent. of ash. At Chimpuluniagu, seven seams have been opened up, one of which is 130 feet thick and is worked opencast. This coal is said to be of excellent quality and to coke easily. Improved plant should make mining here very profitable.

South-east of Hermannstadt coal occurs on the right bank of the Zibin, below Talmesch, in the Middle Miocene formation. The question whether the coal would repay working on a large scale can only be settled by a trial-drift or a shaft, but the authors do not anticipate favourable results.

*Peat* of good quality, burning slowly with but little smoke, and leaving 10·4 per cent. of ash, occurs in the Rohrbach valley. Unfortunately the real extent of the deposit is not great: it had been much overestimated by one of the Hungarian surveyors in 1892-93. East of Freck, in the Alt valley, is another deposit of peat, of Interglacial age. It is very impure, and leaves on an average 50·8 per cent. of ash.

*Graphite* of rather poor quality occurs among the crystalline schists south of Resinar, in a phyllite which contains a good deal of both fresh and decomposed pyrites. Specimens of the graphite taken from the outcrop show it to be very impure and quite unsuitable for the manufacture of crucibles. There is, however, the possibility that a trial-boring might reveal much purer graphite at some depth below the surface. The authors think that the experiment should be made.

*Petroleum and Natural Gas.*—The occurrence of petroleum in the south-eastern corner of Transylvania, at Sósmezö, is well known, but oil has not been so far struck in the central areas of the province. There are, however, one or two hopeful indications (if somewhat remote) in the shape of fairly numerous occurrences of natural gas, and in the shape of a great salt-bearing formation of the same age (Miocene) as those strata which in Rumania and Galicia contain oil in payable quantity. The problem is one that awaits settlement by means of trial-borings.

*Manganese-ores* are recorded from Bistra, on the Strimba, but bad weather and other circumstances prevented the authors from gauging the extent or value of the deposits.

*Gold.*—The placer of Oláh Pián is still being worked, and the authors think that, thanks to the improvements in method (of washing, etc.) achieved in recent times, it would pay to work many apparently exhausted or neglected deposits. They also direct attention to the gold-mine of Porkura, where auriferous pyrites with native gold occurs in veins, in andesite and dacite.

*Marble* and *Gypsum* also occur, but one does not gather that the occurrences are such as to be of any considerable economic importance. L. L. B.

(2) *Beiträge zur Kenntniss der Goldlagerstätten des Siebenbürgischen Erzgebirges. By* M. SEMPER. *Abhandlungen der Königlich Preussischen Geologischen Landesanstalt, new series, No.* 33 (1900), *xiv. and* 219 *pages and* 36 *figures.*

*Gold.*—The gold-bearing deposits of Transylvania are conveniently grouped into five districts, as follows:—I., the Eastern Csetrás Range (Deposits 1 to 5 of the accompanying Table); II., the Western Csetrás Range (Deposits 6 to 9); III., the Judenberg-Stanisza Group (Deposits 10 to 13); IV., the Verespaták Group (Deposits 14 to 17); V., the Offenbánya Group (Deposit 18). All these districts are comprised within the Transylvanian Erzgebirge, of which they take up, however, only a small portion.

The chief gold-bearing rocks are trachytic eruptives of Tertiary age, and throughout the whole region their connexion with the occurrence of gold is more or less distinctly evident. In the Offenbánya district, these eruptives are underlain by Archæan mica-schists and reef-like granular limestones: in the last-named gold occurs also.

Gold has been found, moreover, in association with a mass of Jurassic reef-limestone isolated amid the melaphyre of Mount Szvregyel, near Boicza; and

early Miocene sedimentaries caught up among the dacites of Nagyág are seamed by gold-bearing veins. At the last-named locality, Lower Miocene clays, sandstones, and conglomerates underlie the great domes of Tertiary eruptives which have been evidently built up by the outpouring of molten lavas from enormous fissures in the earth's crust. With regard to the succession in time of these eruptives, the dacites and rhyolites appear to be the oldest, and the hornblende-andesites are the most recent. At Verespaták and Bucsum, the order of eruption seems to have been:—(1) older compact rhyolite with quartz-inclusions; (2) dacite; and (3) younger, porous, pumiceous rhyolite, free from quartz.

Table I. gives a conspectus of the gold-bearing deposits and the associated eruptive rocks.

TABLE I.—GOLD-BEARING DEPOSITS.

| No. | Auriferous Deposits (Localities). | Eruptive Associated Rocks: Mesozoic | Eruptive Associated Rocks: Kainozoic. | Rocks presumably concerned in the Genesis of the Auriferous Deposits. |
|---|---|---|---|---|
| 1 | Nagyág ... ... | ... ... | Hornblendic dacite | |
| 2 | Hondol .. ... | .. | Hornblende-andesite | |
| 3 | Troicza-Tresztya | Melaphyre | Hornblende-andesite | |
| 4 | Boicza ... | (quartz-porphyry | .. | Hornblende-andesite |
| 5 | Kisalmás-Porkura | Melaphyre | Dacite poor in hornblende | |
| 6 | Felső-Kajanel .. | ... .. | Dacite poor in hornblende, and hornblende-andesite | |
| 7 | Muszári ... ... | ... ... | Hypersthene-hornblende-dacite passing into hornblende-andesite | |
| 8 | Barza group ... | ... ... | Hypersthene-hornblende-andesite | |
| 9 | Czebe Valley . | ... ... | Augite-bearing hornblende-andesite | |
| 10 | Fericzel-Stanitza | .. | | |
| 11 | Tekerő ... . | Melaphyre | ... .. ... ... ... ... | |
| 12 | Faczebáj ... | | Hornblende-andesite | |
| 13 | Nagy Almás | | | |
| 14 | Verespaták | Lower Carpathian Sandstone | Dacite poor in hornblende & rhyolites | Hornblende-andesite |
| 15 | Bucsum .. | | Rhyolite-breccia | |
| 16 | Korabia-Vulkoj .. | ... | Hornblende-andesite | |
| 17 | Botes .. | Upper Carpathian Sandstone | ... ... ... | Hornblende-andesite |
| 18 | Offenbánya | ... ... | Dacite rich in hornblende, passing into hornblende-andesite | |

The auriferous deposits are for the most part true veins, none of them much more than 2 to 4 inches thick; nor are they remarkable for continuity in strike and pitch. Here and there, indeed, some preserve a regular strike for about 3,500 feet. On the whole, the predominant strike is north and south; but as the genesis of the deposits is traceable to earth-movements intimately connected with the eruption of the volcanic rocks, regularity of strike can hardly be looked for. The salbands with their numerous slickensides afford another testimony to the connexion between the earth-movements and the formation of the ores. These salbands are usually characterized by a well-defined cleft often filled with marly material, and kaolinization is of frequent occurrence. In such cases, the masses of neighbouring rock, decomposed into

kaolin and calcareous marl are bespattered with fairly large crystals of pyrites. The dacites and rhyolites of Verespaták are peculiar, in showing no sign of kaolinization in the immediate neighbourhood of the auriferous veins. There are frequent signs of subsequent impregnation with silica.

When a number of veins cross each other, there is considerable enrichment of the ores along the sides of the fissures, and the intervening highly kaolinized country is often so charged with auriferous pyrites that it pays to work it. Of a different character are the extremely irregular deposits in the granular limestone of Offenbánya: here the ore-body seems to be made up of infillings of pipe-like cavities which were leached out of the limestone at its contact with the eruptive rocks.

Anything resembling placer-deposits occurs only in the plain of the Körös, near Körösbánya. Here gipsies wash for gold certain river-gravels, and it is quite possible that the precious metal which these contain has been carried down with the débris from the ore-crushing works higher up stream.

The gold of the above-described deposits is always accompanied by silver; it is generally associated with pyrites, but seldom occurs as a telluride. Some of the gold is separable from the pyrites by amalgamation, but about half of the whole output has to be extracted from the pyrites in the wet way. In addition to its association with ordinary pyrites, gold is sometimes found in payable quantities in marcasite, copper-pyrites, fahlore, and galena. The visible free gold occurs in three forms:—(1) crystalline, intergrown with other minerals; (2) in druses; and (3) in fairly large, rounded grains upon pyrites. The native gold of Nagyág, and in part that of Verespaták, appears to have been derived from tellurides: the other gold-occurrences are doubtless of primary origin. The average fineness of the gold ranges, according to Posepny, from 620 to 750, but it is difficult to estimate the richness of any particular deposit, as the variation from place to place is extreme.

Silver is present in the form of the native metal, silver-glance, pyrargyrite, stephanite, horn-silver, and has been also found in fahlores, galena and tellurides. Manganiferous minerals are typical constituents of these auriferous deposits, and in many cases they make up the greater part of the vein-stuff, as at Verespaták, Nagyág, and Valea Mori.

It is noticeable that the richness of the veins bears a certain relation to the intensity of kaolinization of the country-rock. Thus, where kaolinic decomposition has not proceeded very far, the veins are richest: where it has gone very far, or has not taken place at all, the ores are poorest. The behaviour of the zinc-minerals is also worthy of remark: at Nagyág, they are never associated with gold, while at Muszári black blende is an infallible indicator of the occurrence of free gold. At Boicza, yellow blende is regarded as a favourable indicator, while black blende is rather unfavourable than otherwise.

L. L. B.

## COAL-BASINS OF CHARLEROI AND THE LOWER SAMBRE, BELGIUM.

*Stratigraphie du Bassin Houiller de Charleroi et de la Basse-Sambre.* By X. STAINIER. *Bulletin de la Société Belge de Géologie, de Paléontologie et d'Hydrologie*, 1901, *vol. xv., pages* 1-60 *and* 1 *plate.*

In the first portion of this important memoir the author describes in great detail the various seams and strata of the coal-field, the lithology of which is summarized in the following synoptical table:—

| Names of Groups and Subdivisions. | Total Thicknesses. | Coal: thickness. | | | Grits. | Shales and Limestones. | Number of Workable Seams. | Ratio of total Coal to the total thickness of Rocks. |
|---|---|---|---|---|---|---|---|---|
| | | Totals. | Workable Seams. | Thin Seams. | | | | |
| | Feet | Feet. | Feet. | Feet. | Feet | Feet. | | Per cent. |
| Sablonnière .. | 423 | 23·18 | 19·90 | 3·28 | 116½ | 283½ | 7 | 5·47 |
| Ardinoises .. | 1,207 | 42·54 | 28·37 | 14·17 | 312 | 853 | 14 | 3·52 |
| Gouffre ... | 846 | 32·63 | 14·76 | 17·87 | 170½ | 643 | 5 | 3·86 |
| Total of Charleroi Group | 2,476 | 98·35 | 63·03 | 35·32 | 599 | 1,779½ | 26 | 3·97 |
| Châtelet Group | 826 | 10·16 | 1·80 | 8·36 | 192 | 624½ | 1 | 1·23 |
| Middle Coal-measures | 3,302 | 108·51 | 64·83 | 43·68 | 791 | 2,404 | 27 | 3·29 |
| Andenne Group | 1,290 | 8·62 | 3·60 | 5·02 | 238 | 1,042 | 2 | 0·67 |
| Chokier Group | 268 | — | — | — | — | — | — | — |
| Total of Coal-measures | 4,860 | 117·13 | 68·43 | 48·70 | 1,029 | 3,446 | 29 | 2·55* |

* This average percentage refers to the whole of the Coal-measures, excluding the Chokier Group.

With regard to this table, the author points out that the total thickness of the Coal-measures (4,860 feet) is far greater than had been previously admitted in the case of the Charleroi coal-field. On the other hand, the number of workable seams is much smaller; from eighty they have dropped to thirty. But the latter number includes only seams that are really workable: another ten or fifteen seams could be added that have been worked locally, but they are not worth taking into account.

Many thrust-faults have superposed on the normal succession masses of strata, which repeat over and over again the same seams. This repetition is so deceptively regular that it simulates a true succession, and has given rise to the now exploded notion of a vast number of distinct seams.

The real depth of the basin is much more considerable than was previously thought: thus, around the town of Charleroi it is necessary to go down to depths exceeding 6,500 feet before striking the Carboniferous Limestone.

It is worth noting the enormous differences between the various subdivisions of the Coal-measures in regard to the respective total thicknesses of coal which they contain. For instance, the Gros Pierre seam, No. 56, occurs about midway up the stratigraphical succession: below it are only three coal-seams, while above it are twenty-five.

With regard to the evidence accumulated from a study of the fossils, the author arrives at the following conclusions:—From base to summit of the series, the fauna of the Charleroi Coal-measures is extremely rich. A gradual change is perceptible in the character of this fauna, as we follow the succession upward: at first purely marine, and even pelagic (that is, fairly deep-water) organisms abound. This strongly marine character little by little gives place to less pronounced marine characteristics, until at the top of the series the fauna is of freshwater origin. But this is a change marked by recurrences indicative of slow evolution, so slow that the denizens of the Coal-measure waters had ample time (in the case of the more adaptable organisms) to accustom themselves to an altered environment.

The same change went on at the same time and in the same manner in the coal-basins of the English Midlands and of Westphalia.

The author considers, therefore, that we should not speak of overlap or unconformities within the Coal-measures: the mass of new palæontological evidence does away with any need for the old hypothesis of sudden invasion of the Coal-measure marshes by the waters of the sea. In place of fossil horizons, scattered, few and far between, we have now a regular, uninterrupted succession of horizons. These show that throughout the entire period of deposition of the Charleroi Coal-measures the conditions were favourable to the development in place of numerous and varied faunas.

In regard to the important question of classification, the author reminds us that the Upper Coal-measures ("Stéphanien" of Prof. A. de Lapparent) do not occur in Belgium, and he proposes the following succession:—

| | | | |
|---|---|---|---|
| Carboniferous System | Coal-measures | Stephanian | |
| | | Westphalian | Charleroi Group |
| | | | Châtelet Group |
| | | Namurian | Andenne Group |
| | | | Chokier Group |
| | Dinantian | | |

"Namurian" is a term proposed by the writer for the lower portion of the "Westphalian" of Prof. de Lapparent; the beds which it includes are very highly developed in the province of Namur. The author does not agree with the Geological Survey of Belgium in grouping the Coal-measure Puddingstone apart from the rest of the Lower Coal-measures: "it is rather a horizon than a group," he says.

For purposes of correlation with British Coal-measures, the author takes as his standard Prof. E. Hull's classification of strata, published in the *Quarterly Journal of the Geological Society*, 1877.* Stage F (Middle Coal-measures) is represented by the Charleroi group. Stage E (Lower Coal-measures) is exactly paralleled in Belgium, and the Rough Rock of Lancashire may be compared with the Belgian Coal-measure Puddingstone: but the last-named is really to be correlated with part of stage D (Millstone Grit). The Gannister coal-seam of Lancashire is precisely similar to the Leopold coal-seam of Charleroi; so too the Bullion coal-seam of Lancashire is in every respect akin to the Sainte-Barbe coal-seam of Floriffoux. Rocks similar to the Yoredale Series, that is, dark barren shales, pass gradually downward into the Carboniferous Limestone of Belgium. Just as in the English Yoredales, they are rich in marine organisms, which exhibit striking affinities with those of the Limestone. So too, stage B (Upper Carboniferous Limestone) may be correlated with the Viséen stage of the Belgian Carboniferous Limestone. The author traces similar resemblances in the Westphalian coal-basin, where, as in England, the Upper Coal-measures, wanting in Belgium, occur.

The coloured folding-plate which accompanies the paper constitutes a very complete synopsis of the Coal-measure succession in the Charleroi coal-field.

L. L. B.

## DECAZEVILLE COAL-FIELD, CENTRAL FRANCE.

*Étude géologique du Bassin Houiller de Decazeville, Aveyron. By* J. Bergeron, — Jardel *and* — Picandet. *Bulletin de la Société géologique de France*, 1900, *series* 3, *vol.* xxviii., *pages* 715-748, *with a map in the text, and* 1 *plate*.

This coal-field, situated some 19 miles north-west of Rodez, the capital town of the department of the Aveyron, occupies a triangular depression in the ancient rocks which is about 12 miles long. The Coal-measures crop out over

* Vol. xxxiii., page 613.

an area little short of 30 square miles, and only a very small portion of the field is masked by more recent deposits (Lower Jurassic limestones in the south and south-west, Eocene marls with white quartz-pebbles in the north).

The authors give a very good account of the literature of the subject, whereby it appears that serious attention was first devoted to this coal-field somewhere about 1806. The Lower Permian or Autunian series rests conformably upon the highest coal-bearing beds; but south of Auzits and east of Firmy the Autunian sandstones and shales clearly overlap the Coal-measures, and lie upon the older mica-schists which surround the basin. This would point to slow and progressive sagging of the basin, and the authors regard the stratigraphical conditions as explicable only on the supposition that the level of the Coal-measure lakes was but little higher than that of the lagoons wherein the earliest Permian deposits were laid down. All other post-Carboniferous strata in this region are distinctly unconformable to the Coal-measures.

The metamorphic rocks which surround the basin are mainly sericite-schists, mica-schists, and granulitized schists, which pass into granulitic gneiss. Some of the mica-schists are highly silicified and rich in graphite. On the southern border of the field, masses of eruptive rock are thrust among the schists, but are so completely kaolinized, that it is hardly possible to determine their nature or origin. The authors also mention intrusive veins of micaceous porphyrite and sills of enstatite-andesite. Moreover, between Girbals and Carabols, all these rocks are seamed by veins of smoky quartz. On the south-west and west are traced apophyses from the granitic mass which rises between Najac and Asprières.

It has already been mentioned that Tertiary marls overlap the Coal-measures on the north, and the authors believe that the extension of the coal-field need not be looked for in that direction, as the evidence points to a northerly pinching-out of the Coal-measures. On the south, on the other hand, the lie of the strata indicates a probable prolongation of the coal-field beneath the Jurassic limestones. On the east is the serpentine-mass of the Puy de Voll, the age of which is shown to be pre-Coal-measure, by the fact that, above the road between Firmy and Noaillac, the Coal-measure grits are seen lying upon the serpentine.

The erosion which took place in Pleistocene times carved deep valleys in the district here described, the most considerable of which is that of the river Lot, cutting across the northern extremity of the coal-field. The other principal valleys are also, in the main, transverse to the field, and at the points where they enter and leave it, the older rocks are plainly seen to form perpendicular walls against which the Coal-measures abut. This is manifestly a case of faulting, but it is hard to tell whether the faults are anterior or posterior in time to the filling-up of the basin. Little patches of Coal-measure basement-conglomerate occur beyond the present boundaries of the field, especially on the west. This basement-conglomerate was evidently faulted up on to the plateau: above it must have lain a vast thickness of Coal-measures and Permian rocks, since swept off by erosion. All was reduced to a dead level before the deposition of the Jurassic strata, and it is plain that the present boundaries are not the original limits of the coal-field. Moreover, the breadth of the field has been decreased by folding.

With regard to the origin of the coal-field, it may be described as due to the formation of several deltas by various simultaneous or successive currents within a lake-basin. The first current to start a delta was that of Haute Serre, then the currents of Longuefont and Luzan were both active, and carried along with them the plant-remains which built up the coal-seams of

Le Soulier. At the same time were being formed in the south of the basin the seams which constitute the Campagnac group. At some points this is represented by a single coal-seam, 82 feet thick, at others by three seams, respectively 10, 20 and 6½ feet thick. While on the south-west the Valzergues current was depositing the measures known by that name, the northerly current of the Pont de Bourran was laying down a series which joined up on the south with the Campagnac group. Then the westerly currents of Moulin du Faux and Viviez came into play, and their deposits, in conjunction with those of the Valzergues current, form the Bourran group, which includes the great seam (sometimes as much as 160 feet thick) worked at Lagrange, Bourran, Combes, Le Fraysse, Le Négrin and Firmy.

The Permian sea invaded the slowly sagging basin from the south. It seems probable, moreover, that the outlet of the old Coal-measure lake was on that side. The faulting and folding to which the basin has been subjected at different periods is discussed at some length, and these phenomena are well-illustrated in the horizontal sections which accompany the paper.

L. L. B.

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## COAL-MEASURE CONGLOMERATES IN THE NORTH OF FRANCE.

(1) *Note sur des Bancs de Poudingue dans le Terrain Houiller de Liévin. By* L. Desailly. (2) *Observations sur le Poudingue houiller de Nœux, Pas de Calais. By* Charles Barrois. *Annales de la Société géologique du Nord,* 1901, *vol. xxx., pages* 13-14 *and* 26-36.

In Belgium, these conglomerates are considered to mark the base of the workable Coal-measures. At Liévin, however, conglomerates occur in the roof of the Eugène and Edouard coal-seams, which form part of the uppermost coal-bearing group of the Pas de Calais. The conglomerate in the roof of the Edouard coal-seam is brecciiform in nature, while that in the roof of the Eugène coal-seam is more distinctly made up of rolled pebbles, some of which are coal, some iron-ore, and others shale. Little veinlets of coal also occur in this conglomerate.

At Noeux also, the conglomerates occur in the upper coal-bearing group, among the grits which separate the St. François coal-seam from the St. Félix coal-seam, and about 40 feet distant from the roof of the former. The conglomerates are made up of small well-rolled pebbles, 50 per cent. of which are quartz, 45 per cent. phthanites, 4 per cent. quartzites, and 1 per cent felspathic rocks: in a word, nothing but the very hardest material is present. The uniformity in size and hardness of the pebbles lead Prof. Barrois to the inference that such conglomerates can neither be of deltaic nor of sea-beach origin, but are distinctly marine, formed at a time when the sea invaded ar area hitherto unoccupied by it.

Curiously enough, these conglomerates, traced at Noeux, Grand Hornu, Hénin-Liétard and Liévin, near the summit of the Coal-measures, bear a striking resemblance to the Andenne conglomerate which as certainly occurs at the base of the Coal-measures of the Franco-Belgian basin. This implies analogy of orographic and topographic conditions at the commencement and at the end of the deposition of the Coal-measures there. The zone of Coal-measure sedimentation seems to have been gradually pushed south-westward by a progressive invasion of sediments pouring in from the north-east.

L. L. B.

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## SOUTHWARD EXTENSION OF THE BOUBLE COAL-BASIN, CENTRAL FRANCE.

*Note sur le Bassin Houiller de la Bouble. By* — ANGLÈS-DAURIAC. *Annales des Mines*, 1901, *series* 9, *vol. xix., pages* 5-46, *with* 3 *figures in the text and* 2 *plates.*

The region dealt with in this paper occupies a length of about 14 miles, in the great Coal-measure belt of the Plateau Central which extends for some 125 miles from Vendes on the south-south-west to Decize on the north-north-east. The general strike of this portion of the belt is north 23 degrees east, and its breadth varies from 2,000 to 4,000 feet.

At the northern end of the basin the coal, cropping out at the surface, has been known from time immemorial, and the mineral is actively worked on the concessions of La Vernade and La Roche, which together constitute what is known as the St. Eloy coal-field. But the workings have never been carried beyond the great Dehaynin fault, against which they all stop abruptly, from the surface down to a depth of 590 feet. That portion of the La Roche concession which lies beyond this fault is still unexplored. In 1896, however, the Tollin No. 1 shaft, put down a little way from the southern boundary of that concession, proved at a depth of 918 feet, good coal-bearing strata belonging to the St. Eloy group. Thereupon, several shafts and borings were started in the district in the hope of proving workable coal, no less than eighteen of them being put down within the last four years. In one sense the results have been disappointing, as no deposit that it would pay to work has been struck; but they have thrown much additional light on the structure of the Bouble coal-basin, and are, to that extent, of practical utility.

The author then defines, and describes in considerable detail, the St. Eloy group of Coal-measures: its principal seams are the so-called Roof seam and the Middle seam, the respective thicknesses of which, with comparatively unimportant partings, run up to 132 and 197 feet. It is, of course, understood that these thicknesses vary within wide limits. It is shown that the seams of La Bouble belong to this group, and that the slight differences observable in the character of the coal are due to the depth at which it occurs, and the presence of fire-damp. The reader is reminded of the general law of diminution in the volatile constituents of coal, the deeper down it occurs. The St. Eloy coal is dry with a long flame; in depth it passes into gas-coal; and doubtless it will be found to pass little by little into coking coal, as one proceeds away from the northern edge of the ancient basin towards its centre.

The author establishes the following succession, in ascending order, in the Coal-measures of this area:—(1) Stage of St. Eloy; (2) stage of the fine sandstones; and (3) stage of the grits and shales. The last-named division has for its uppermost beds very coarse grits and conglomerates, and upon these rests the Permian. The pebbles in the conglomerate (granites, microgranites, aplites, quartz, gneisses, mica-schists, etc.) seem to have been derived from different localities spread over a wide area, and do not encourage the notion of torrential or local delta-deposits.

The sections of the St. Eloy mines, which illustrate this paper, show the extreme contortion of the masses of coal and accompanying measures; but there is "method in this madness"—a general direction of folding has been proved, distinctly oblique to the general strike of the basin, with which it forms an angle of about 20 degrees. The faulting and folding observed in the mines of La Bouble, and the inferences deducible therefrom as to the tectonics of the area, are discussed at great length.

In conclusion, the author points out that in addition to the evidence of the extension of the St. Eloy group afforded by the Tollin shaft, the borings of La Croizette and Le Vernadel provided very strong presumptive evidence of still further extension of the coal-field. The practical difficulties are the variations in depth and the lack of continuity of occurrence of particular horizons. At any rate, the original synclinal wherein the Coal-measures were deposited appears to have been very much broader than the present basin—but perhaps in this instance we ought rather to speak of it as an area fractured by dislocation than as a true synclinal. L. L. B.

## IRON-ORES OF LE BRAY, FRANCE.

*Sur les Minerais de Fer et les Eaux de la Nappe de l'Hauterivien du Bray.* By N. DE MERCEY. *Bulletin de la Société géologique de France*, 1900, *series* 3, *vol. xxviii., pages* 793-797.

These iron-ores occur in two beds, an upper and a lower, respectively 36 and 20 inches thick, amid sands which are overlain and underlain by plastic clays. Where the ore-beds lie below the hydrostatic level they are unaltered pisolitic carbonates, where they lie above that level they have been decomposed to hydrated oxides. They were worked at one time, as the old slag-heaps testify, and the author estimates that the total output probably ranged between 4,800 and 6,800 tons per acre. The ore-beds continue regularly in depth as do the other beds of the group in which they are comprised, and there seems to be no particular reason why mining operations should not be started again in this area. The essential condition is the erection of pumping-engines, as it is calculated that about 2 tons of water will have to be pumped from the strata for every ton of ore extracted. The deeper down the workings are carried, the more likely are they to be extended in a south-westerly direction. The paper is largely devoted to the explanation of how it comes about that the sands here are heavily watered, and to calculations of the quantity of water that would have to be dealt with. L. L. B.

## MANGANIFEROUS MINERALS OF THE UPPER PYRENEES, FRANCE.

*Sur les Minéraux des Gisements manganésifères des Hautes-Pyrénées.* By A. LACROIX. *Bulletin de la Société Française de Minéralogie* 1900, *vol. xxiii., pages* 251-255.

The Devonian shales and limestones of the Serre d'Azet are impregnated with rhodonite, friedelite and dialogite, passing at the outcrop into manganite, which itself decomposes into polianite (pyrolusite). Workings have long been opened up in these deposits, some on the Louron valley side of the massif, at Adervielle, others on the Aure valley side, at Vielle-Aure.

At Adervielle, the rhodonite and dialogite form compact rocks, banded like the barren limestones. The author is especially interested in certain veins about ½ inch thick, of pink spathic dialogite, and describes the various minerals associated with it, among which is tephroite. The fissures of the manganiferous rocks are often encrusted with crystals of hyaline quartz and albite.

At Vielle-Aure, friedelite is more abundant, and with it are associated beautiful little crystals of grossularian garnet. On the waste-heap, the author found large rhombohedra of lilac-pink dialogite which, for size, can only be matched by those from Alicante county, Colorado.

The manganese oxides of both of the above-mentioned ore-deposits are mostly earthy or compact: sometimes, however, they contain geodes encrusted with crystals of steel-grey manganite. L. L. B.

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## CARBONATED IRON-ORE OF NORMANDY.

*Note sur le Minerai de Fer carbonaté de Normandie et sur la Calcination des Carbonates de Fer au Four à Cuve.* By L. PRALON. *Annales des Mines,* 1901, *series* 9, *vol. xix., pages* 125-148, *with a map and* 4 *sections in the text.*

The existence of iron-ores in Normandy and Britanny has been known for untold generations, and the traces of ancient workings and derelict foundries are noticeable in more than one locality. The most considerable ore-deposits are of Silurian age, and consist in some cases of specular iron-ore and magnetite (as near Segré in Anjou), or of red hæmatites (as at St. Remy, May-sur-Orne, and St. André in Lower Normandy). Disseminated more or less irregularly all over the area are deposits of hydrated hæmatite or limonite, some of which are also of Silurian age, but the greater number are of much more recent origin. The limonites are especially abundant in Northern Britanny (department of Ille-et-Vilaine), as, for instance, in the neighbourhood of Redon. A good deal of prospecting and exploration-work has been done of late years among the limonites of Camöel, etc.; but without any result of practical importance, on account of the great dissemination and extreme irregularity of the deposits.

The only considerable mine that is at work on the Silurian iron-ores of Normandy, is the St. Remy mine, in the Calvados, which produces annually from 80,000 to 100,000 tons of splendid red hæmatite; this contains a sufficient percentage of phosphorus to be suitable for the Thomas process. The neighbouring mines of May-sur-Orne and St. André yield a very small output: the ore is much poorer in iron, contains more silica, and makes more waste in mining. At Segré, at the other end of the Silurian belt, until within recent years, several thousand tons of magnetite and specular ore were got: but the Segré ore is of so compact a nature, and so highly siliceous, that it is extremely unsuitable for the blast-furnace, and the author believes that this mine will have to be abandoned.

At Bourberouge, near Mortain, some spasmodic attempts have been made at working limonites apparently of Silurian age, and mining concessions granted for working iron-ores at Jurques and Halouze in Lower Normandy have been scarcely utilized.

Such was the state of affairs when the Denain and Anzin Company, in search of a richer ore than that of Lorraine, but suitable for mixing with it, started to explore methodically the Silurian strata of Normandy with the hope of finding another such deposit as that of St. Remy. But in seeking for hæmatite they discovered ores consisting almost entirely of carbonate: the exploration-work was carried on by means of nine shafts, etc., dotted along the entire Silurian belt from Le Châtellier near Halouze to the ridge of Mont-en-Géraume. It proved that the limonites, the mining of which formed the object of the old workings, were really the decomposition-product of an oolitic carbonate of iron, forming a bed, 6¼ to 8 feet thick, regularly interstratified between the Armorican Grit and the *Calymene*-shales. The ancient miners had simply worked the limonites, opencast, to depths of 50 and 60 feet or so. In the neighbourhood of the granites, the eruption of which appears to have been the originating cause of the tectonic disturbances in this area, the oolitic

carbonate is seen to be metamorphosed into red, compact, anhydrous hæmatite, absolutely identical with the ore of St. Remy. A sample of ore from one of the localities (La Ferrière-aux-Etangs) midway between Halouze and Mont-en-Géraume was analysed at Denain: it is a so-called *salard*, or carbonate, partly decomposed by infiltration of air and surface-waters. The chief percentages are as follows:—Carbon dioxide, 13·8; protoxide of iron, 27·59; peroxide of iron, 30·66; silica, 14·8; alumina, 2·61; lime, 2·90; and phosphoric acid, 1·46. By simple roasting it seems that the ordinary carbonate-ore can be improved from a tenour of about 40 per cent. of iron to one of 54 per cent., and is then extremely suitable for combination in the blast-furnace with Lorraine ores. The knowledge of this fact has already brought into the field a number of competitors eager to share with the Denain and Anzin Company the privilege of working the Norman deposits.

Anything, however, at all comparable with the great series of iron-ore beds of Lorraine is not to be looked for in the area here described. The ferruginous oolite of Normandy appears to consist of only one bed, the maximum thickness of which does not far exceed 8 feet: though, in places, the repetition due to folding gives it a greater apparent thickness. In other localities, the ore-bed is tilted on end, faulted, and shattered by tectonic disturbances. Elsewhere, it thins out to such an extent as not to repay working, or, as at Jurques, it sometimes becomes so highly siliceous as to lose all industrial value. But what ore is of value is richer than that of Lorraine, and the geological position of the deposits may be compared with that of the iron-carbonates of the province of Leon in Spain, which are interbedded with Silurian shales startlingly similar to the *Calymene*-shales of Normandy.

The Norman carbonates, thanks perhaps to the siliceous gangue which may be said to "give them backbone," do not crumble unduly on handling in the mine or in the course of preliminary roasting. The amount of fuel that should be used is small, and the author cites with approval the system adopted by the Sommorostro Company, who burn rather less than 22 pounds of coal for every metric ton of calcined ore or 17 pounds per ton of raw ore. The calcining-furnace must be of moderate dimensions, and the free circulation of air through the mass should be favoured by arranging for its inflow at the base and below the floor.

The author does not expect any metallurgical industry of importance to arise in Lower Normandy, but thinks that the use of the Norman iron-ores as an enrichment for the Lorraine ores will make the ironworks of the north of France largely independent of the ores hitherto imported from abroad.

L. L. B.

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## LIME-PHOSPHATES OF PICARDY, FRANCE.

*Les Phosphates de Chaux de Picardie. By* J. GOSSELET. *Livret-guide du VIII.e Congrès géologique international, Excursion No.* 16, *pages* 11-20, *with figures in the text.*

In Picardy, phosphates of lime occur in the form (1) of phosphatized chalk, and (2) of phosphatic sand. The deposits are of limited extent, and following them along for a certain distance one soon notes a progressive diminution in the grains of phosphate and a gradual passage into ordinary chalk (the horizon is that of *Belemnitella quadrata*). So too there is, as a rule, a gradual impoverishment in any given deposit from the base upwards. As there is occasional interbedding of rich and barren strata, it is evident that the process of phosphatization was intermittent. Speaking generally, the phosphatized

chalk occurs in ellipsoidal basins varying in diameter from 300 to 10,000 feet, and at the same time the deposits are lenticular. At the base is nearly always a conglomerate of chalk-nodules rich in phosphate. This is described in detail, as also the underlying hard bed with its brown patinated crust (the hard bed has in many instances been eroded away). The history of the genesis of the phosphatized chalk is summed up as follows:—

(1) Pause in the sedimentation of the white chalk.

(2) Penetration of its surface by a phosphate-of-lime solution which hardened it and altered it into a richly phosphatized chalk.

(3) Emergence (or lixiviation?) of the hardened surface. Deposition of a [brown] crust of phosphate of lime, with encrustation of organisms (*Ostrea, Spondylus, Serpula*, etc.).

(4) Formation of a breccia or pseudo-conglomerate at the expense of the hard bed. Continuation of the encrusting process.

(5) Perforation by large boring-organisms. Destruction and redeposition of much of the hard rock. Formation of a conglomerate and deposition of phosphatized chalk.

(6) Deposition of normal [phosphatized] chalk.

The phosphatic sand is almost entirely made up of little grains of phosphate of lime. It forms a layer on the walls of pockets in the phosphatized chalk, or even in the lower white chalk. The middle of the pocket is generally filled by loam, or clay-with-flints, and sometimes there is a little Tertiary sand between the loam and the phosphatic sand. The last-named is no doubt the outcome of the chemical action of rainwater, charged with carbonic acid, on the phosphatized chalk. The pockets dissolved out of the chalk vary in depth to a maximum of 33 feet: they are often in close juxtaposition.

Sections are figured and described of the deposits at Etaves, Méricourt, Templeux le Guérard, Hem-Monacu and Haravesnes. In the first-named the phosphatic sand has been worked out, but brown chalk containing from 25 to 50 per cent. of phosphate remains. At the other localities three or more bands of richly phosphatized chalk are being worked. No statistics of output, etc., are given in this paper. L. L. B.

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# II.—BAROMETER, THERMOMETER, ETC., READINGS FOR THE YEAR 1900.

BY M. WALTON BROWN.

The barometer, thermometer, etc., readings have been supplied by permission of the authorities of Glasgow and Kew Observatories, and give some idea of the variations of atmospheric temperature and pressure in the intervening districts in which mining operations are chiefly carried on in this country.

The barometer at Kew is 34 feet, and at Glasgow is 180 feet, above sea-level. The barometer readings at Glasgow have been reduced to 32 feet above sea-level, by the addition of 0·150 inch to each reading, and the barometrical readings at both observatories are reduced to 32° Fahr.

The statistics of fatal explosions in collieries are obtained from the annual reports of H.M. Inspectors of Mines, and are also printed upon the diagrams (Plates XX. and XXI.) recording the meteorological observations.

The hours from midnight until 12 noon are A.M., and from noon until midnight are P.M.

TABLE I.—SUMMARY OF EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1900.*

| Mines-inspection Districts. | Fatal Accidents. | | | Non-fatal Accidents. | |
|---|---|---|---|---|---|
| | No. | Deaths. | Injured. | No. | Injured. |
| Durham ... ... ... | 0 | 0 | 0 | 7 | 13 |
| Ireland ... ... ... | 0 | 0 | 0 | 0 | 0 |
| Liverpool ... ... .. | 1 | 8 | 2 | 2 | 8 |
| Manchester ... ... | 0 | 0 | 0 | 0 | 0 |
| Midland ... ... ... | 1 | 2 | 2 | 7* | 5 |
| Newcastle-upon-Tyne ... | 2 | 5 | 10 | 7* | 9 |
| Scotland, East ... ... | 6 | 8 | 5 | 30 | 38 |
| Do. West ... ... | 8 | 14 | 7 | 27 | 35 |
| South Wales ... ... | 3 | 4 | 1 | 23 | 40 |
| South-Western ... ... | 0 | 0 | 0 | 2 | 2 |
| Staffordshire, North ... | 0 | 0 | 0 | 5 | 9 |
| Do. South ... | 3 | 3 | 1 | 10 | 11 |
| Yorkshire ... ... .. | 1 | 1 | 1 | 8 | 8 |
| Totals ... ... | 25 | 45 | 29 | 128* | 178 |

* Including explosions by which no persons were injured.

TABLE II.—LIST OF FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1900.

| 1900. | Colliery. | Mines-inspection Districts. | Deaths. | No. of Persons Injured. |
|---|---|---|---|---|
| Jan. 8, 3·0 a.m. | Niddrie ... ... | Scotland, East ... | 1 | 1 |
| Feb. 12, 1·0 p.m. | Carbarns ... ... | Do. ... | 3 | 1 |
| „ 22, 11·0 a.m. | Glespin ... ... | Do. ... | 1 | 2 |
| Mar. 8, 8·0 „ | Himley ... ... | Staffordshire, South... | 1 | 0 |
| „ 12, 9·30 „ | Pumpherston (oil-shale) ... ... | Scotland, East ... | 1 | 0 |
| „ 25, 11·0 p.m. | Dumbreck (No. 2 Pit) | Scotland, West ... | 1 | 0 |
| „ 26, 6·15 a.m. | Cowdenbeath ... | Scotland, East ... | 1 | 1 |
| April 7, 0·45 „ | Cadley Hill ... ... | Midland ... | 2 | 2 |
| „ 9, 2·0 p.m. | Walsall Wood ... | Staffordshire, South... | 1 | 1 |
| „ 12, 8·15 a.m. | Holytown (No. 12 Pit) | Scotland, West ... | 2 | 2 |
| May 28, 8·30 „ | Clynhebog ... ... | South Wales ... | 2 | 1 |
| June 10, 6·45 p.m. | Clynmil Drift ... | Do. ... | 1 | 0 |
| „ 22, 3·0 a.m. | Garw Fechan ... | Do ... | 1 | 0 |
| „ 29, 5·0 „ | No. 3 Old Boston ... | Liverpoo ... ... | 8 | 2 |
| Aug. 12, 10·30 p.m. | Tannochside (No. 3 Pit) ... ... | Scotland, West ... | 1 | 1 |
| „ 17, 1·30 „ | Portland (No. 5 Pit) | Do. ... | 6 | 2 |
| Sept. 3, 5·30 a.m. | Kenmuirhill (No. 2 Pit) ... ... | Do. ... | 1 | 0 |
| Oct. 3, 1·30 „ | Hattonrigg (Nos. 3 and 4 Pits) ... | Do. ... | 1 | 0 |
| „ 9, 3·0 „ | Fieldhouse ... ... | Yorkshire ... ... | 1 | 1 |
| Nov. 16, 11·30 „ | Preston ... ... | Newcastle-upon-Tyne | 4 | 9 |
| „ 24, 11·0 „ | Gilmilnscroft (No. 4 Pit) ... ... | Scotland, West ... | 1 | 0 |
| „ 30, 11·30 p.m. | Dechmont (No. 1 Pit) | Do. ... | 1 | 2 |
| Dec. 3, 11·30 „ | Oatlands ... ... | Newcastle-upon-Tyne | 1 | 1 |
| „ 9, 11·45 „ | Hamstead ... ... | Staffordshire, South... | 1 | 0 |
| „ 28, 12·30 „ | Ross .. ... ... | Scotland, East .. | 1 | 0 |
| | | Totals ... | 45 | 29 |

TABLE III.—LIST OF NON-FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1900.

| 1900. | Colliery. | Mines-inspection Districts. | No. of Persons Injured. |
|---|---|---|---|
| Jan. 13, 8.30 p.m.... | Silverdale (Holly Wood Pit) ... ... | Staffordshire, North ... | 1 |
| „ 18, 10·0 a.m.... | South Durham .. | Durham ... ... | 3 |
| „ 22, 2·30 p.m.... | Do. ... | Do. ... ... | 2 |
| „ 26, 6·30 a.m.... | Cwmteg ... ... | South Wales ... ... | 1 |
| „ 27, 7·0 „ ... | Byers Green ... . | Durham ... ... | 1 |
| „ 29, 10·0 „ ... | Auchenharvie (No. 5 Pit) | Scotland, West ... | 1 |
| Feb. 6, 9·0 „ ... | Blackwell (B winning) | Midland ... ... | 1 |
| „ 6, 9·30 „ ... | Philpstoun (oil-shale) | Scotland, East ... | 1 |
| „ 9, 1·30 p.m.... | Graig ... ... ... | South Wales ... ... | 2 |
| „ 13, 1·0 a.m.... | Auchencruive (Mossblow No. 1 Pit) ... | Scotland, West .. | 1 |
| „ 13, 7·30 „ ... | Rowley Station ... | Staffordshire, South ... | 1 |
| „ 16, 6·50 „ ... | Barblues ... ... | Scotland, East ... | 1 |
| „ 17, 11·30 „ ... | High Hazels ... ... | Yorkshire ... ... | 1 |
| „ 19, 9·0 „ ... | Woodhall (No. 1 Pit) | Scotland, West ... | 1 |
| „ 19, 12·0 noon... | Gilmilnscroft (No. 4 Pit)... ... ... | Do. ... ... | 1 |
| „ 20, 8·30 a.m.... | Afton (No. 1 Pit) ... | Do. ... ... | 2 |

TABLE III.—*Continued.*

| 1900. | Colliery. | Mines-Inspection Districts. | No. of Persons Injured. |
|---|---|---|---|
| Feb. 21, 5·0 p.m.... | Avondale ... ... | Scotland, East ... | 1 |
| " 23, 11·0 a.m.... | Coppice ... ... | Staffordshire, South ... | 1 |
| " 27, 7·0 " ... | Craighead (No. 2 Pit) | Scotland, West ... | 2 |
| Mar 1, 1·15 p.m.... | Westminster ... ... | Liverpool ... ... | 6 |
| " 4, 7·30 a.m.... | Clynmil ... ... | South Wales ... ... | 1 |
| " 13, 8·0 p.m.... | Gospel Oak ... ... | Staffordshire, South ... | 1 |
| " 15, 12·30 " ... | Roman Camp (oil-shale) ... ... | Scotland, East ... | 1 |
| " 21, 2·30 " ... | Park Hall ... ... | Midland ... ... | 1 |
| " 23, 2·0 a.m.... | Park Mill ... ... | Yorkshire ... ... | 1 |
| " 27, 9·0 " ... | Allanshaw ... ... | Scotland, East . | 1 |
| " 28, 10·45 " ... | Liverton (ironstone) | Durham ... ... | 1 |
| April 3, 7·50 p.m.... | Langley Park ... | Do. .. | 2 |
| " 3, 12·0 noon | Onllwyn ... ... | South Wales ... ... | 1 |
| " 4, 5·0 a.m.... | Kenmuirhill (No. 2 Pit) | Scotland, West ... | 1 |
| " 6, 9·0 " ... | Tydderwen ... ... | South Wales ... ... | 1 |
| " 12, 7·0 p.m.... | Garw Fechan ... | Do. ... | 1 |
| " 18, 2·30 a.m... | Newton (No. 1 Pit) ... | Scotland, West ... | 1 |
| " 26, 3·30 " ... | Whitfield ... ... | Staffordshire, North ... | 2 |
| " 26, 11·30 p.m.... | Allanton ... ... | Scotland, East ... | 2 |
| " 27, 11·0 " ... | Carronrigg ... ... | Scotland, West ... | 1 |
| " 27, 12·0 noon | Cwrt-y-Bettws .. | South Wales ... ... | 1 |
| May 1, 1·10 p.m.... | Pentrich ... | Midland ... ... | 0 |
| " 1, 11·0 " ... | Bardykes (No. 2 Pit)... | Scotland, West ... | 1 |
| " 2, 6·15 a.m.... | Glentore ... ... | Scotland, East ... | 1 |
| " 2, 6·45 " ... | Camp (No. 1 Pit) ... | Scotland, West ... | 1 |
| " 3, 3·30 p.m.... | Guéret's Graigola ... | South Wales ... ... | 1 |
| " 10, 0·45 a.m.... | Ravensworth (Betty Pit) ... ... | Newcastle-upon-Tyne | 2 |
| " 14, 10·0 " ... | Cwm ... ... ... | South Wales ... ... | 4 |
| " 14, 10·0 " ... | Dunnikier ... ... | Scotland, East ... | 1 |
| " 16, 9·30 " ... | Blaen-cae-Gurwen ... | South Wales ... ... | 2 |
| " 16, 11·0 " ... | Ravensworth (Shop Pit) | Newcastle-upon-Tyne | 2 |
| " 22, 9·15 " ... | Cannock Chase ... | Staffordshire, South ... | 1 |
| " 26, 7·0 " ... | Holytown (No. 5 Pit) | Scotland, West ... | 1 |
| June 12, 1·0 p.m.... | Collenna ... ... | South Wales ... ... | 1 |
| " 13, 11·0 a.m.... | Loftus (ironstone) ... | Durham ... ... | 3 |
| " 15, 9·0 " .. | Victoria (No. 2 Pit) ... (ironstone) ... | Scotland, West ... | 1 |
| " 16, 1·0 " ... | Emley Moor ... ... | Yorkshire ... ... | 1 |
| " 17, 11·0 p.m.... | Newton (No. 1 Pit) ... | Scotland, West ... | 1 |
| " 18, 5·0 a.m.... | Stanton (Nadins) ... | Midland ... . | 1 |
| " 18, 9·0 " ... | Himley ... ... | Staffordshire, South ... | 1 |
| " 22, 11·30 " ... | Aldridge ... ... | Do. ... | 1 |
| " 25, 12·30 p.m.... | Glyn ... ... ... | South Wales ... ... | 2 |
| " 27, 10·45 a.m.... | Ingliston (oil-shale) ... | Scotland, East ... | 2 |
| July 5, 10·30 " ... | Kenmuirhill (No. 2 Pit) | Scotland, West ... | 1 |
| " 5, 11·30 p.m.... | Kilton (ironstone) ... | Durham ... ... | 1 |
| " 9, 1·30 " ... | Jordan ... ... | Yorkshire ... ... | 1 |
| " 10, 7·10 a.m.... | Holmes (oil-shale) ... | Scotland, East ... | 1 |
| " 11, 2·45 p.m.... | Wallyford ... ... | Do. ... | 1 |
| " 11, 7·0 " ... | Kelty ... ... ... | Do. ... | 2 |
| " 19, 6·20 a.m.... | Avonhead ... ... | Do. ... | 1 |
| " 23, 8·0 " ... | Barblues ... ... | Do. ... | 1 |
| " 23, 10·0 " ... | Varteg Hill ... ... | South Western ... | 1 |
| " 24, 9·0 p.m.... | Brownyside ... ... | Scotland, East ... | 2 |
| " 25, 4·0 a.m.... | Collenna ... ... | South Wales ... ... | 4 |
| " 26, 0·30 " .. | Newmarket ... ... | Yorkshire ... ... | 1 |
| " 28, 6·30 " ... | Blairhall (ironstone)... | Scotland, East ... | 1 |
| " 30, 6·30 " ... | Tirfounder ... ... | South Wales ... ... | 1 |

TABLE III.—*Continued.*

| 1900. | | | Colliery. | Mines-inspection Districts. | No. of Persons Injured. |
|---|---|---|---|---|---|
| July | 31, | 7·30 p.m.... | Great Western ... | South Wales ... ... | 7 |
| „ | 31, | 8·0 „ ... | Glangarnant ... ... | Do. ... | 1 |
| Aug. | 1, | 7·30 a.m.... | Foxfield ... ... | Staffordshire, North ... | 1 |
| „ | 1, | 5·15 p.m.... | Pemberton (Queen Pit) | Liverpool ... ... | 2 |
| „ | 2, | 0·30 a.m.... | Newton (No. 1 Pit) ... | Scotland, West ... | 1 |
| „ | 3, | 10·30 „ ... | Longwork ... ... | South Wales ... ... | 1 |
| „ | 9, | 7·0 „ ... | Cornsilloch ... ... | Scotland, East ... | 4 |
| „ | 12, | 10·30 p.m. .. | Ravenshall (No. 43 Pit) | Scotland, West ... | 1 |
| „ | 14, | 4·30 a.m.... | East Holywell ... | Newcastle-upon-Tyne | 1 |
| „ | 17, | 8·30 „ ... | Brownyside ... ... | Scotland, East ... | 1 |
| „ | 17, | 11·20 „ ... | Wood Farm ... ... | Staffordshire, South ... | 1 |
| „ | 17, | 3·0 p.m.... | Cannock Chase ... | Do. ... | 1 |
| „ | 17, | 12·30 „ ... | Portland (No. 5 Pit) | Scotland, West ... | 1 |
| „ | 22, | 5·40 a.m... | Pumpherston (oil-shale) ... ... | Scotland, East ... | 1 |
| „ | 24, | 9·15 „ ... | South Birtley .. | Newcastle-upon-Tyne | 2 |
| „ | 25, | 10·0 „ ... | Hamilton Palace (No. 2 Pit) ... ... | Scotland, West ... | 3 |
| „ | 25, | 1·30 p.m.... | Orbiston (No. 1 Pit)... | Do. ... | 1 |
| „ | 27, | 3·0 a.m.... | Harrington (No. 7 Pit) | Newcastle-upon-Tyne | 1 |
| Sept. | 4, | 11·30 p.m.... | Backworth (Blue Bell Pit) ... ... | Do. .. | 1 |
| „ | 14, | 8·30 a.m.... | High Hazels ... .. | Yorkshire ... ... | 1 |
| „ | 15, | 5·30 „ .. | Whitehill ... ... | Scotland, West ... | 1 |
| „ | 15, | 12·30 p.m.... | Cadder (No. 17 Pit) ... | Do. ... ... | 2 |
| „ | 20, | 7·30 a.m.... | Trowell Moor ... ... | Midland ... ... | 0 |
| „ | 28, | 5·30 „ ... | Philpstoun (oil-shale) | Scotland, East ... | 1 |
| Oct. | 3, | 8·20 „ ... | Rowley Station ... | Staffordshire, South ... | 2 |
| „ | 3, | 12·0 noon... | Pumpherston(oil-shale) | Scotland, East ... | 1 |
| „ | 13, | 9·0 a.m.... | Glencraig ... ... | Do. ... ... | 2 |
| „ | 17, | 1·0 p.m.... | Cannock Chase ... | Staffordshire, South ... | 1 |
| „ | 18, | 2·0 a.m.... | Bridgeness ... ... | Scotland, East ... | 1 |
| „ | 22, | 11·30 „ ... | Shelton (Rowhurst No. 2 Pit) ... ... | Staffordshire, North .. | 2 |
| „ | 22, | 12·30 p.m.... | Glanwern ... .. | South Wales ... ... | 1 |
| „ | 23, | 11·30 a.m.... | Cornsilloch ... ... | Scotland, East ... | 1 |
| „ | 30, | 8·30 p.m.... | Linlithgow (oil-shale) | Do. ... ... | 1 |
| „ | 31, | 4·0 a.m.... | Gorseinon ... ... | South Wales ... ... | 3 |
| Nov. | 4, | 9·0 „ ... | Wharncliffe ... ... | Yorkshire ... ... | 1 |
| „ | 5, | 6·15 „ ... | Easterhill .. ... | Scotland, West ... | 1 |
| „ | 5, | 7·30 p.m.... | Clara Vale ... ... | Newcastle-upon-Tyne | 0 |
| „ | 6, | 8·30 „ .. | Enterkine (No. 9 Pit) | Scotland, West ... | 4 |
| „ | 14, | 7·30 a.m.... | Forkneuk (oil-shale)... | Scotland, East ... | 1 |
| „ | 14, | 11·0 „ ... | High Hazels ... ... | Yorkshire ... ... | 1 |
| „ | 15, | 2·0 „ ... | Ashton Vale ... ... | South-Western ... | 1 |
| „ | 15, | 8·15 „ .. | Glascote ... ... | Midland ... ... | 2 |
| „ | 15, | 10·0 „ ... | Plumptre ... ... | Do. ... | 0 |
| „ | 27, | 8·0 „ ... | Newton (No. 1 Pit) ... | Scotland, West ... | 1 |
| „ | 27, | 1·0 p.m.... | Glynea ... ... ... | South Wales ... .. | 1 |
| „ | 27, | 8·0 „ ... | Shelton (Racecourse No. 3 Pit) ... ... | Staffordshire, North ... | 3 |
| „ | 30, | 12·30 „ ... | Dunnikier ... ... | Scotland, East ... | 1 |
| Dec. | 7, | 8·30 „ .. | Barblues ... ... | Do. ... | 1 |
| „ | 9, | 7·45 „ ... | Braichycymmer Darran ... ... ... | South Wales ... ... | 1 |
| „ | 12, | 8·30 a.m.... | Cwmteg ... ... | Do. ... | 1 |
| „ | 20, | 1·20 p.m.... | Souterhouse (No. 1 Pit) | Scotland, West ... | 1 |
| „ | 22, | 7·0 a.m.... | Glencraig ... ... | Scotland, East ... | 1 |
| „ | 25, | 8·0 p.m.... | Broomhouse ... ... | Scotland, West ... | 1 |
| „ | 27, | 9·30 a.m.... | Empire ... ... | South Wales ... ... | 1 |
| „ | 31, | 6·30 „ ... | Seafield (oil-shale) ... | Scotland, East ... | 1 |
| | | | | Total ... ... | 178 |

TABLE IV.—BAROMETER, THERMOMETER, ETC., READINGS, 1900.

JANUARY, 1900.

| KEW. | | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BAROMETER. | | | | TEMPERATURE. | | Direction of wind at noon. | | BAROMETER. | | | | TEMPERATURE. | | Direction of wind at noon. |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | |
| 1 | 29·887 | 29·910 | 29·857 | 29·757 | 44·0 | 31·0 | ESE | 1 | 29·748 | 29·814 | 29·836 | 29·812 | 39·5 | 33·6 | ENE |
| 2 | 29·576 | 29·524 | 29·511 | 29·470 | 51·0 | 43·3 | SSW | 2 | 29·705 | 29·380 | 29·445 | 29·388 | 41·1 | 35·9 | E |
| 3 | 29·396 | 29·274 | 29·216 | 29·324 | 47·4 | 41·0 | S | 3 | 29·319 | 29·351 | 29·494 | 29·666 | 41·1 | 37·6 | NE |
| 4 | 29·451 | 29·610 | 29·660 | 29·729 | 42·9 | 37·0 | N | 4 | 29·752 | 29·826 | 29·869 | 29·935 | 40·5 | 35·8 | NNW |
| 5 | 29·763 | 29·882 | 29·935 | 30·012 | 40·9 | 37·0 | NNE | 5 | 29·968 | 29·977 | 29·930 | 29·859 | 37·1 | 30·2 | SE |
| 6 | 30·025 | 30·031 | 29·924 | 29·760 | 42·4 | 29·0 | S | 6 | 29·730 | 29·595 | 29·524 | 29·516 | 40·2 | 35·2 | S |
| 7 | 29·602 | 29·747 | 29·945 | 30·113 | 45·3 | 35·2 | NNW | 7 | 29·561 | 29·741 | 29·867 | 29·889 | 41·1 | 35·2 | W |
| 8 | 30·166 | 30·135 | 30·139 | 30·099 | 47·4 | 31·2 | SW | 8 | 29·807 | 29·901 | 29·833 | 29·717 | 44·5 | 38·1 | WSW |
| 9 | 30·036 | 30·092 | 30·141 | 30·190 | 46·9 | 36·9 | NW | 9 | 29·779 | 29·832 | 29·875 | 29·908 | 44·3 | 38·3 | WSW |
| 10 | 30·171 | 30·180 | 30·236 | 30·344 | 44·9 | 35·9 | NW | 10 | 29·996 | 30·147 | 30·257 | 30·330 | 42·4 | 36·2 | WNW |
| 11 | 30·399 | 30·442 | 30·422 | 30·419 | 41·1 | 34·5 | NNW | 11 | 30·326 | 30·297 | 30·375 | 30·270 | 39·1 | 34·2 | NE |
| 12 | 30·404 | 30·426 | 30·379 | 30·370 | 40·4 | 32·3 | SE | 12 | 30·209 | 30·175 | 30·135 | 30·140 | 47·1 | 38·5 | SW |
| 13 | 30·321 | 30·258 | 30·149 | 30·093 | 37·2 | 28·3 | S | 13 | 30·063 | 29·952 | 29·799 | 29·787 | 44·3 | 41·3 | S |
| 14 | 30·034 | 30·036 | 29·959 | 29·899 | 36·8 | 27·9 | S | 14 | 29·768 | 29·729 | 29·579 | 29·373 | 43·7 | 40·4 | SSW |
| 15 | 29·715 | 29·534 | 29·440 | 29·527 | 45·3 | 31·1 | SSW | 15 | 29·198 | 29·152 | 29·184 | 29·218 | 44·9 | 34·6 | W |
| 16 | 29·504 | 29·432 | 29·498 | 29·649 | 46·0 | 37·0 | SW | 16 | 29·207 | 29·269 | 29·346 | 29·418 | 40·1 | 35·2 | WSW |
| 17 | 29·629 | 29·525 | 29·482 | 29·573 | 50·1 | 37·1 | SW | 17 | 29·394 | 29·313 | 29·235 | 29·229 | 41·5 | 36·2 | SE |
| 18 | 29·720 | 29·901 | 30·070 | 30·236 | 45·2 | 35·1 | WNW | 18 | 29·479 | 29·747 | 29·935 | 29·975 | 41·3 | 35·1 | W |
| 19 | 30·288 | 30·246 | 30·122 | 30·016 | 48·6 | 31·3 | SSW | 19 | 29·804 | 29·531 | 29·581 | 29·705 | 47·9 | 38·1 | WSW |
| 20 | 30·101 | 30·195 | 30·178 | 30·255 | 46·7 | 29·8 | W | 20 | 29·831 | 29·931 | 29·974 | 30·046 | 43·5 | 37·2 | W |
| 21 | 30·270 | 30·193 | 29·966 | 29·904 | 50·3 | 28·0 | NNW | 21 | 30·013 | 29·820 | 29·563 | 29·703 | 44·2 | 37·6 | S |
| 22 | 30·046 | 30·067 | 30·004 | 30·047 | 49·9 | 42·4 | SW | 22 | 29·687 | 29·495 | 29·537 | 29·612 | 51·2 | 39·3 | W |
| 23 | 30·046 | 30·110 | 30·079 | 30·053 | 51·2 | 46·6 | WSW | 23 | 29·650 | 29·720 | 29·816 | 29·784 | 50·2 | 47·4 | WSW |
| 24 | 29·928 | 29·760 | 29·652 | 29·924 | 53·0 | 42·6 | SW | 24 | 29·626 | 29·457 | 29·462 | 29·610 | 48·1 | 38·9 | SSW |
| 25 | 30·095 | 30·283 | 30·341 | 30·387 | 49·8 | 41·0 | WNW | 25 | 29·844 | 30·020 | 30·083 | 30·043 | 47·9 | 37·1 | WSW |
| 26 | 30·314 | 30·162 | 29·975 | 29·911 | 49·2 | 41·0 | SW | 26 | 29·877 | 29·577 | 29·621 | 29·611 | 47·5 | 33·6 | W |
| 27 | 29·823 | 29·662 | 29·422 | 29·391 | 42·1 | 34·2 | SW | 27 | 29·461 | 29·330 | 29·293 | 29·244 | 38·0 | 34·1 | W |
| 28 | 29·317 | 29·263 | 29·305 | 29·462 | 38·3 | 32·0 | N | 28 | 29·236 | 29·483 | 29·685 | 29·874 | 39·3 | 31·9 | NNE |
| 29 | 29·645 | 29·742 | 29·716 | 29·690 | 39·9 | 35·4 | N | 29 | 29·950 | 29·924 | 29·924 | 29·954 | 39·4 | 34·1 | NE |
| 30 | 29·672 | 29·664 | 29·657 | 29·700 | 39·2 | 36·8 | NNE | 30 | 29·890 | 29·916 | 29·988 | 30·006 | 38·3 | 34·3 | ENE |
| 31 | 29·732 | 29·793 | 29·779 | 29·779 | 39·7 | 35·1 | NE | 31 | 29·974 | 29·981 | 29·925 | 29·839 | 37·9 | 34·8 | NE |

FEBRUARY, 1900.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 29·735 | 29·705 | 29·643 | 29·633 | 35·8 | 33·3 | E | 1 | 29·727 | 29·699 | 29·647 | 29·771 | 36·3 | 30·3 | NE |
| 2 | 29·626 | 29·680 | 29·709 | 29·726 | 37·1 | 32·6 | NE | 2 | 29·847 | 29·913 | 29·911 | 29·932 | 34·3 | 26·1 | S |
| 3 | 29·731 | 29·761 | 29·746 | 29·761 | 34·6 | 32·8 | N | 3 | 29·920 | 29·968 | 29·926 | 29·909 | 34·8 | 28·3 | E |
| 4 | 29·734 | 29·707 | 29·639 | 29·628 | 36·4 | 32·8 | N | 4 | 29·852 | 29·803 | 29·736 | 29·741 | 37·0 | 28·8 | N |
| 5 | 29·601 | 29·599 | 29·570 | 29·587 | 37·1 | 32·9 | N | 5 | 29·714 | 29·739 | 29·717 | 29·776 | 35·8 | 25·6 | SSW |
| 6 | 29·624 | 29·733 | 29·777 | 29·855 | 38·4 | 30·1 | NNE | 6 | 29·831 | 29·911 | 29·911 | 29·915 | 34·3 | 28·1 | N |
| 7 | 29·583 | 29·892 | 29·836 | 29·841 | 34·2 | 24·8 | N | 7 | 29·819 | 29·783 | 29·752 | 29·803 | 32·1 | 25·0 | NW |
| 8 | 29·883 | 29·970 | 29·975 | 30·018 | 34·1 | 21·6 | N | 8 | 29·839 | 29·872 | 29·839 | 29·851 | 34·1 | 19·4 | ENE |
| 9 | 30·012 | 29·996 | 29·937 | 29·922 | 32·1 | 19·0 | NE | 9 | 29·822 | 29·828 | 29·766 | 29·731 | 32·5 | 28·1 | E |
| 10 | 29·836 | 29·752 | 29·532 | 29·241 | 36·3 | 19·5 | S | 10 | 29·695 | 29·646 | 29·514 | 29·425 | 29·4 | 19·2 | NNE |
| 11 | 29·095 | 29·221 | 29·410 | 29·493 | 36·0 | 24·3 | WNW | 11 | 29·315 | 29·284 | 29·270 | 29·282 | 30·2 | 15·2 | W |
| 12 | 29·463 | 29·396 | 29·350 | 29·449 | 38·2 | 19·1 | W | 12 | 29·253 | 29·223 | 29·204 | 29·236 | 35·3 | 15·3 | S |
| 13 | 29·569 | 29·589 | 29·359 | 29·079 | 36·1 | 24·9 | E | 13 | 29·300 | 29·364 | 29·380 | 29·428 | 38·1 | 31·9 | SSW |
| 14 | 29·164 | 29·679 | 29·980 | 30·085 | 38·2 | 26·8 | NNW | 14 | 29·522 | 29·686 | 29·761 | 29·761 | 38·5 | 26·3 | E |
| 15 | 30·012 | 29·846 | 29·425 | 29·140 | 45·4 | 29·0 | SE | 15 | 29·693 | 29·508 | 29·057 | 28·551 | 38·9 | 32·6 | SE |
| 16 | 29·046 | 29·207 | 29·409 | 29·424 | 47·1 | 38·3 | W | 16 | 28·486 | 28·631 | 28·815 | 28·860 | 42·1 | 33·8 | WSW |
| 17 | 29·242 | 29·212 | 29·013 | 29·132 | 47·2 | 37·0 | SSW | 17 | 28·721 | 28·799 | 28·863 | 28·938 | 43·0 | 36·3 | W |
| 18 | 29·243 | 29·333 | 29·254 | 29·106 | 48·3 | 33·7 | SW | 18 | 28·915 | 28·984 | 28·921 | 28·800 | 43·6 | 36·0 | SW |
| 19 | 28·934 | 28·708 | 28·510 | 28·507 | 51·5 | 42·2 | SW | 19 | 28·695 | 28·540 | 28·428 | 28·434 | 38·2 | 35·2 | E |
| 20 | 28·708 | 28·758 | 28·839 | 29·071 | 47·1 | 35·9 | SW | 20 | 28·540 | 28·712 | 28·914 | 29·112 | 39·3 | 30·6 | N |
| 21 | 29·286 | 29·504 | 29·598 | 29·576 | 43·3 | 33·6 | W | 21 | 29·242 | 29·355 | 29·401 | 29·343 | 38·9 | 29·9 | WNW |
| 22 | 29·400 | 29·368 | 29·436 | 29·589 | 53·5 | 40·0 | WSW | 22 | 29·198 | 29·187 | 29·240 | 29·358 | 36·6 | 29·4 | E |
| 23 | 29·563 | 29·560 | 29·605 | 29·651 | 55·7 | 41·7 | SW | 23 | 29·310 | 29·195 | 29·126 | 29·258 | 49·9 | 35·6 | SSE |
| 24 | 29·644 | 29·698 | 29·708 | 29·762 | 56·3 | 49·2 | S | 24 | 29·378 | 29·460 | 29·516 | 29·605 | 49·8 | 43·3 | SW |
| 25 | 29·683 | 29·774 | 29·798 | 29·767 | 54·9 | 49·0 | SSW | 25 | 29·663 | 29·761 | 29·808 | 29·885 | 47·1 | 39·4 | NE |
| 26 | 29·613 | 29·668 | 29·512 | 29·502 | 56·7 | 45·0 | SE | 26 | 29·877 | 29·869 | 29·795 | 29·748 | 41·1 | 34·0 | ENE |
| 27 | 29·436 | 29·447 | 29·509 | 29·599 | 49·7 | 46·7 | NW | 27 | 29·693 | 29·735 | 29·846 | 29·936 | 40·2 | 34·9 | ENE |
| 28 | 29·682 | 29·[illegible]56 | 29·945 | 30·051 | 47·8 | 38·6 | NE | 28 | 29·995 | 30·114 | 30·181 | 30·263 | 43·1 | 35·3 | ENE |

MARCH, 1900.

| KEW. | | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BAROMETER. | | | | TEMPERATURE. | | | | BAROMETER. | | | | TEMPERATURE. | | |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. |
| 1 | 30·069 | 30·176 | 30·228 | 30·326 | 41·3 | 33·8 | NE | 1 | 30·315 | 30·390 | 30·414 | 30·433 | 41·4 | 35·9 | ENE |
| 2 | 30·282 | 30·265 | 30·209 | 30·229 | 42·1 | 33·3 | N | 2 | 30·389 | 30·370 | 30·256 | 30·234 | 44·6 | 29·6 | W |
| 3 | 30·191 | 30·193 | 30·152 | 30·148 | 43·1 | 36·9 | NW | 3 | 30·213 | 30·222 | 30·208 | 30·235 | 43·0 | 35·7 | NE |
| 4 | 30·107 | 30·140 | 30·115 | 30·125 | 40·1 | 35·7 | NE | 4 | 30·238 | 30·242 | 30·205 | 30·224 | 43·4 | 30·5 | WSW |
| 5 | 30·114 | 30·185 | 30·225 | 30·278 | 39·9 | 36·3 | NNE | 5 | 30·221 | 30·258 | 30·266 | 30·294 | 40·8 | 33·3 | ESE |
| 6 | 30·272 | 30·295 | 30·274 | 30·286 | 39·7 | 37·7 | N | 6 | 30·288 | 30·261 | 30·227 | 30·260 | 45·3 | 36·1 | NW |
| 7 | 30·271 | 30·280 | 30·241 | 30·252 | 42·2 | 35·4 | NNW | 7 | 30·248 | 30·267 | 30·209 | 30·206 | 42·8 | 30·9 | WNW |
| 8 | 30·226 | 30·251 | 30·207 | 30·216 | 41·9 | 38·3 | N | 8 | 30·195 | 30·213 | 30·200 | 30·221 | 40·3 | 32·4 | NE |
| 9 | 30·185 | 30·206 | 30·173 | 30·230 | 46·9 | 37·7 | E | 9 | 30·197 | 30·215 | 30·199 | 30·241 | 41·3 | 36·3 | E |
| 10 | 30·233 | 30·268 | 30·220 | 30·242 | 54·2 | 38·4 | E | 10 | 30·242 | 30·269 | 30·219 | 30·239 | 46·1 | 33·3 | W |
| 11 | 30·200 | 30·217 | 30·193 | 30·278 | 52·1 | 38·9 | NE | 11 | 30·211 | 30·231 | 30·209 | 30·294 | 52·2 | 33·5 | WNW |
| 12 | 30·337 | 30·440 | 30·398 | 30·456 | 56·0 | 34·8 | N | 12 | 30·338 | 30·379 | 30·354 | 30·334 | 48·4 | 38·1 | WNW |
| 13 | 30·393 | 30·465 | 30·510 | 30·626 | [illegible] | 37·7 | NE | 13 | 30·403 | 30·531 | 30·582 | 30·627 | 49·1 | 39·5 | NNW |
| 14 | 30·587 | 30·567 | 30·487 | 30·447 | 52·0 | 34·5 | N | 14 | 30·575 | 30·561 | 30·412 | 30·303 | 50·4 | 41·9 | WNW |
| 15 | 30·316 | 30·157 | 29·935 | 29·770 | 49·1 | 42·1 | W | 15 | 30·097 | 29·813 | 29·617 | 29·507 | 48·6 | 34·1 | W |
| 16 | 29·580 | 29·542 | 29·510 | 29·512 | 43·6 | 32·4 | NW | 16 | 29·473 | 29·484 | 29·507 | 29·515 | 37·3 | 30·4 | NW |
| 17 | 29·486 | 29·484 | 29·458 | 29·496 | 40·0 | 27·9 | NW | 17 | 29·476 | 29·462 | 29·411 | 29·429 | 37·8 | 28·3 | E |
| 18 | 29·495 | 29·493 | 29·377 | 29·288 | 42·2 | 24·9 | SE | 18 | 29·420 | 29·440 | 29·387 | 29·398 | 38·0 | 26·1 | E |
| 19 | 29·191 | 29·253 | 29·304 | 29·355 | 46·1 | 33·3 | S | 19 | 29·320 | 29·275 | 29·258 | 29·430 | 38·3 | 28·4 | NE |
| 20 | 29·447 | 29·605 | 29·697 | 29·789 | 52·1 | 36·0 | SSW | 20 | 29·518 | 29·613 | 29·781 | 29·898 | 39·4 | 32·2 | ENE |
| 21 | 29·779 | 29·760 | 29·672 | 29·587 | 47·2 | 34·2 | NE | 21 | 29·902 | 29·905 | 29·850 | 29·872 | 39·6 | 36·0 | ENE |
| 22 | 29·476 | 29·474 | 29·473 | 29·567 | 46·0 | 39·9 | NE | 22 | 29·878 | 29·886 | 29·900 | 29·971 | 39·8 | 36·3 | E |
| 23 | 29·652 | 29·796 | 29·843 | 29·913 | 45·8 | 36·1 | NE | 23 | 30·025 | 30·106 | 30·124 | 30·134 | 42·1 | 37·2 | E |
| 24 | 29·895 | 29·908 | 29·892 | 29·941 | 41·9 | 35·1 | NNE | 24 | 30·114 | 30·146 | 30·142 | 30·153 | 40·8 | 36·1 | E |
| 25 | 29·909 | 29·900 | 29·808 | 29·759 | 41·3 | 35·3 | N | 25 | 30·084 | 29·956 | 29·859 | 29·855 | 42·8 | 28·9 | WNW |
| 26 | 29·683 | 29·678 | 29·653 | 29·680 | 41·2 | 32·7 | N | 26 | 29·820 | 29·824 | 29·783 | 29·783 | 40·4 | 31·1 | NNE |
| 27 | 29·670 | 29·690 | 29·640 | 29·617 | 41·3 | 33·3 | NW | 27 | 29·712 | 29·609 | 29·442 | 29·443 | 39·3 | 31·3 | SW |
| 28 | 29·501 | 29·553 | 29·627 | 29·763 | 42·3 | 33·0 | N | 28 | 29·561 | 29·717 | 29·762 | 29·828 | 43·3 | 33·1 | NNE |
| 29 | 29·824 | 29·814 | 29·901 | 29·961 | 45·4 | 30·5 | N | 29 | 29·818 | 29·821 | 29·809 | 29·977 | 42·8 | 32·0 | NNW |
| 30 | 29·985 | 30·075 | 30·092 | 30·222 | 46·7 | 27·1 | NE | 30 | 29·919 | 30·000 | 30·159 | 30·164 | 45·1 | 30·9 | E |
| 31 | 30·281 | 30·361 | 30·330 | 30·371 | 47·1 | 30·0 | ESE | 31 | 30·233 | 30·289 | 30·245 | 30·241 | 49·9 | 31·5 | WSW |

APRIL, 1900.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30·314 | 30·277 | 30·148 | 30·156 | 42·3 | 29·4 | ENE | 1 | 30·177 | 30·135 | 30·050 | 30·071 | 49·5 | 35·3 | WSW |
| 2 | 30·115 | 30·079 | 29·963 | 29·934 | 48·8 | 27·9 | WNW | 2 | 30·034 | 30·000 | 29·916 | 29·843 | 46·7 | 33·2 | WSW |
| 3 | 29·838 | 29·745 | 29·566 | 29·279 | 51·9 | 32·6 | WSW | 3 | 29·718 | 29·576 | 29·337 | 29·201 | 45·2 | 39·4 | E |
| 4 | 29·215 | 29·308 | 29·360 | 29·439 | 53·8 | 39·3 | W | 4 | 29·129 | 29·144 | 29·175 | 29·283 | 47·1 | 37·1 | WNW |
| 5 | 29·470 | 29·573 | 29·645 | 29·798 | 49·7 | 39·1 | N | 5 | 29·379 | 29·483 | 29·600 | 29·728 | 47·1 | 36·3 | W |
| 6 | 29·859 | 29·892 | 29·777 | 29·721 | 52·0 | 34·7 | WSW | 6 | 29·738 | 29·705 | 29·649 | 29·666 | 47·4 | 33·9 | S |
| 7 | 29·667 | 29·699 | 29·722 | 29·847 | 48·2 | 37·8 | SE | 7 | 29·694 | 29·801 | 29·859 | 29·935 | 46·6 | 36·1 | E |
| 8 | 29·877 | 29·876 | 29·841 | 29·818 | 47·0 | 37·8 | N | 8 | 29·935 | 29·906 | 29·805 | 29·736 | 47·4 | 32·9 | ESE |
| 9 | 29·746 | 29·734 | 29·669 | 29·693 | 52·2 | 30·8 | W | 9 | 29·634 | 29·589 | 29·545 | 29·518 | 49·4 | 40·1 | NW |
| 10 | 29·719 | 29·755 | 29·780 | 29·819 | 54·8 | 38·9 | W | 10 | 29·391 | 29·451 | 29·532 | 29·478 | 49·1 | 37·8 | NW |
| 11 | 29·682 | 29·647 | 29·536 | 29·404 | 56·8 | 43·8 | SW | 11 | 29·191 | 29·202 | 29·106 | 29·259 | 50·5 | 39·4 | WSW |
| 12 | 29·621 | 29·795 | 29·767 | 29·629 | 57·0 | 44·9 | W | 12 | 29·385 | 29·398 | 29·181 | 29·080 | 49·3 | 42·6 | SW |
| 13 | 29·612 | 29·[illegible]64 | 29·816 | 29·986 | 57·3 | 45·1 | W | 13 | 28·990 | 29·303 | 29·663 | 29·790 | 50·2 | 39·6 | WNW |
| 14 | 30·040 | 30·011 | 30·001 | 30·068 | 62·2 | 43·1 | WSW | 14 | 29·693 | 29·575 | 29·659 | 29·693 | 53·1 | 41·9 | W |
| 15 | 30·015 | 29·949 | 29·882 | 29·959 | 55·6 | 42·2 | SW | 15 | 29·565 | 29·396 | 29·472 | 29·430 | 51·1 | 40·9 | W |
| 16 | 29·923 | 29·869 | 29·920 | 30·104 | 54·8 | 41·8 | WNW | 16 | 29·274 | 29·570 | 29·742 | 30·004 | 52·9 | 41·8 | WNW |
| 17 | 30·209 | 30·225 | 30·177 | 30·237 | 52·1 | 39·3 | WSW | 17 | 29·974 | 29·924 | 30·062 | 30·189 | 55·1 | 41·6 | NW |
| 18 | 30·293 | 30·375 | 30·399 | 30·478 | 61·1 | 41·9 | NNE | 18 | 30·225 | 30·285 | 30·335 | 30·398 | 52·6 | 42·6 | W |
| 19 | 30·518 | 30·549 | 30·501 | 30·524 | 64·2 | 45·4 | S | 19 | 30·429 | 30·446 | 30·429 | 30·430 | 60·4 | 46·1 | SW |
| 20 | 30·520 | 30·510 | 30·421 | 30·411 | 67·9 | 43·0 | SE | 20 | 30·417 | 30·411 | 30·330 | 30·312 | 66·7 | 44·9 | W |
| 21 | 30·384 | 30·374 | 30·264 | 30·260 | 73·4 | 41·0 | SW | 21 | 30·290 | 30·279 | 30·202 | 30·220 | 66·9 | 44·9 | W |
| 22 | 30·214 | 30·199 | 30·102 | 30·101 | 71·9 | 44·8 | NW | 22 | 30·199 | 30·211 | 30·143 | 30·138 | 57·2 | 43·1 | ENE |
| 23 | 30·106 | 30·128 | 30·043 | 30·056 | 60·9 | 44·1 | NE | 23 | 30·115 | 30·105 | 30·034 | 30·035 | 61·5 | 47·3 | W |
| 24 | 30·027 | 30·016 | 29·948 | 29·928 | 60·2 | 40·7 | NNE | 24 | 30·016 | 30·014 | 29·941 | 29·953 | 58·3 | 48·6 | NE |
| 25 | 29·884 | 29·981 | 30·060 | 30·143 | 48·5 | 36·1 | NE | 25 | 30·045 | 30·112 | 30·132 | 30·167 | 52·1 | 38·0 | E |
| 26 | 30·179 | 30·189 | 30·070 | 30·023 | 51·9 | 31·7 | SSE | 26 | 30·141 | 30·070 | 29·952 | 29·892 | 48·5 | 33·8 | W |
| 27 | 29·961 | 29·972 | 30·011 | 30·084 | 50·0 | 35·0 | N | 27 | 29·973 | 30·056 | 30·042 | 30·056 | 52·3 | 38·1 | E |
| 28 | 30·104 | 30·116 | 30·002 | 29·963 | 51·5 | 39·2 | NNE | 28 | 30·004 | 29·960 | 29·844 | 29·744 | 50·5 | 37·1 | W |
| 29 | 29·889 | 29·848 | 29·775 | 29·766 | 56·1 | 35·9 | W | 29 | 29·557 | 29·484 | 29·577 | 29·654 | 54·9 | 43·0 | NW |
| 30 | 29·747 | 29·771 | 29·758 | 29·817 | 56·2 | 49·0 | SW | 30 | 29·677 | 29·711 | 29·690 | 29·660 | 50·8 | 39·9 | W |

## MAY, 1900.

| KEW. | | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer. | | | | Temperature. | | | | Barometer. | | | | Temperature. | | |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. |
| 1 | 29·887 | 29·996 | 30·013 | 30·043 | 61·0 | 46·5 | NNW | 1 | 29·720 | 29·875 | 29·879 | 29·780 | 52·3 | 40·3 | SW |
| 2 | 29·987 | 29·954 | 29·863 | 29·812 | 63·5 | 42·1 | SW | 2 | 29·600 | 29·597 | 29·583 | 29·526 | 61·2 | 45·3 | SW |
| 3 | 29·589 | 29·440 | 29·577 | 29·830 | 58·1 | 43·0 | SW | 3 | 29·259 | 29·004 | 29·009 | 29·339 | 53·1 | 42·6 | SSW |
| 4 | 29·921 | 29·968 | 29·937 | 29·916 | 61·9 | 44·7 | SSW | 4 | 29·470 | 29·452 | 29·489 | 29·523 | 56·2 | 42·1 | SSW |
| 5 | 29·854 | 29·854 | 29·835 | 29·816 | 68·1 | 50·4 | S | 5 | 29·495 | 29·537 | 29·641 | 29·695 | 58·1 | 47·4 | SW |
| 6 | 29·747 | 29·618 | 29·470 | 29·449 | 69·3 | 48·3 | E | 6 | 29·698 | 29·679 | 29·594 | 29·517 | 57·9 | 42·2 | SE |
| 7 | 29·479 | 29·522 | 29·601 | 29·644 | 64·2 | 45·1 | SW | 7 | 29·340 | 29·378 | 29·476 | 29·581 | 55·9 | 44·9 | SSW |
| 8 | 29·632 | 29·611 | 29·586 | 29·604 | 61·1 | 42·4 | NNE | 8 | 29·637 | 29·678 | 29·659 | 29·682 | 63·3 | 42·3 | NNE |
| 9 | 29·538 | 29·540 | 29·614 | 29·736 | 55·5 | 49·2 | W | 9 | 29·702 | 29·765 | 29·861 | 29·999 | 54·6 | 45·3 | E |
| 10 | 29·804 | 29·922 | 29·969 | 30·032 | 52·6 | 43·5 | NE | 10 | 30·047 | 30·073 | 30·041 | 30·056 | 49·5 | 41·9 | E |
| 11 | 30·031 | 30·038 | 29·983 | 30·027 | 56·3 | 37·3 | E | 11 | 30·040 | 30·041 | 30·028 | 30·053 | 49·3 | 38·9 | E |
| 12 | 30·026 | 30·047 | 29·985 | 29·978 | 50·7 | 44·6 | E | 12 | 30·057 | 30·064 | 30·055 | 30·110 | 48·5 | 37·3 | E |
| 13 | 29·987 | 30·011 | 30·005 | 30·035 | 48·7 | 40·0 | NE | 13 | 30·152 | 30·202 | * | * | 50·2 | 35·6 | E |
| 14 | 29·970 | 29·970 | 29·931 | 30·025 | 53·0 | 38·3 | NE | 14 | 30·240 | 30·206 | 30·141 | 30·198 | 56·5 | 37·3 | NE |
| 15 | 30·022 | 30·076 | 30·047 | 30·117 | 55·1 | 39·0 | NE | 15 | 30·196 | 30·192 | 30·113 | 30·145 | 65·7 | 39·9 | W |
| 16 | 30·085 | 30·101 | 30·105 | 30·154 | 51·6 | 37·2 | N | 16 | 30·182 | 30·195 | 30·123 | 30·123 | 69·8 | 46·5 | N |
| 17 | 30·131 | 30·123 | 29·999 | 29·989 | 63·1 | 43·0 | N | 17 | 30·089 | 30·097 | 30·041 | 30·033 | 59·1 | 47·4 | WNW |
| 18 | 29·958 | 29·963 | 29·953 | 30·017 | 55·2 | 44·0 | E | 18 | 30·032 | 30·032 | 29·989 | 30·022 | 54·7 | 42·3 | NE |
| 19 | 30·026 | 30·082 | 30·076 | 30·105 | 57·0 | 42·7 | NNW | 19 | 30·027 | 30·034 | 30·005 | 29·997 | 56·6 | 38·1 | W |
| 20 | 30·105 | 30·104 | 30·032 | 30·033 | 63·9 | 37·2 | WSW | 20 | 29·930 | 29·903 | 29·877 | 29·838 | 56·6 | 46·3 | W |
| 21 | 29·976 | 29·932 | 29·864 | 29·798 | 62·9 | 44·0 | SW | 21 | 29·753 | 29·669 | 29·465 | 29·363 | 52·1 | 48·6 | SSE |
| 22 | 29·693 | 29·634 | 29·600 | 29·609 | 56·8 | 50·2 | SSW | 22 | 29·274 | 29·264 | 29·191 | 29·126 | 55·9 | 48·2 | SW |
| 23 | 29·608 | 29·627 | 29·659 | 29·678 | 60·2 | 47·7 | SW | 23 | 29·227 | 29·307 | 29·371 | 29·461 | 54·9 | 46·4 | WSW |
| 24 | 29·642 | 29·658 | 29·711 | 29·821 | 58·5 | 48·2 | WSW | 24 | 29·521 | 29·595 | 29·651 | 29·766 | 57·4 | 41·4 | W |
| 25 | 29·898 | 29·970 | 29·997 | 30·081 | 60·1 | 45·0 | NW | 25 | 29·845 | 29·937 | 29·978 | 30·050 | 59·4 | 45·9 | W |
| 26 | 30·153 | 30·218 | 30·195 | 30·250 | 64·4 | 43·3 | E | 26 | 30·082 | 30·081 | 30·063 | 30·066 | 62·1 | 45·6 | SSW |
| 27 | 30·242 | 30·234 | 30·197 | 30·209 | 68·7 | 41·5 | SSW | 27 | 30·010 | 29·974 | 29·940 | 29·899 | 56·3 | 50·4 | S |
| 28 | 30·198 | 30·215 | 30·222 | 30·284 | 66·0 | 50·1 | W | 28 | 29·871 | 29·907 | 30·076 | 30·168 | 57·6 | 49·5 | W |
| 29 | 30·296 | 30·288 | 30·252 | 30·304 | 63·9 | 46·7 | NW | 29 | 30·227 | 30·266 | 30·277 | 30·318 | 64·1 | 46·3 | NW |
| 30 | 30·301 | 30·308 | 30·267 | 30·273 | 58·1 | 48·2 | N | 30 | 30·332 | 30·319 | 30·267 | 30·316 | 64 4 | 55·6 | E |
| 31 | 30·249 | 30·252 | 30·224 | 30·233 | 55·2 | 47·6 | N | 31 | 30·316 | 30·343 | 30·359 | 30·399 | 51·6 | 47·4 | E |

## JUNE, 1900.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30·177 | 30·147 | 30·098 | 30·073 | 52·7 | 48·1 | NNE | 1 | 30·390 | 30·386 | 30·315 | 30·326 | 61·8 | 45·3 | E |
| 2 | 30·033 | 30·040 | 29·992 | 30·004 | 62·1 | 48·4 | NNE | 2 | 30·291 | 30·268 | 30·174 | 30·175 | 65·0 | 45·3 | E |
| 3 | 29·965 | 29·944 | 29·886 | 29·915 | 68·8 | 50·3 | N | 3 | 30·157 | 30·123 | 30·059 | 30·076 | 72·7 | 43·3 | E |
| 4 | 29·884 | 29·891 | 29·891 | 29·944 | 73·3 | 49·1 | NE | 4 | 30·076 | 30·054 | 29·999 | 30·038 | 68·7 | 43·3 | NE |
| 5 | 29·924 | 29·934 | 29·919 | 29·960 | 61·6 | 46·1 | N | 5 | 30·025 | 30·010 | 29·939 | 29·945 | 64·2 | 44·9 | NE |
| 6 | 29·937 | 29·941 | 29·872 | 29·876 | 72·7 | 47·8 | WSW | 6 | 29·912 | 29·863 | 29·782 | 29·752 | 70·9 | 46·1 | WSW |
| 7 | 29·845 | 29·843 | 29·791 | 29·806 | 64·9 | 51·8 | WSW | 7 | 29·699 | 29·674 | 29·637 | 29·639 | 60·6 | 47·5 | N |
| 8 | 29·781 | 29·805 | 29·845 | 29·916 | 65·9 | 51·6 | W | 8 | 29·646 | 29·668 | 29·675 | 29·702 | 58·3 | 47·1 | NE |
| 9 | 29·917 | 29·946 | 29·933 | 29·947 | 67·7 | 52·1 | SW | 9 | 29·686 | 29·670 | 29·644 | 29·691 | 60·8 | 47·7 | S |
| 10 | 29·888 | 29·865 | 29·786 | 29·768 | 80·6 | 52·8 | S | 10 | 29·715 | 29·728 | 29·683 | 29·678 | 74·1 | 54·5 | S |
| 11 | 29·820 | 29·831 | 29·760 | 29·825 | 86·5 | 59·1 | SE | 11 | 29·741 | 29·819 | 29·803 | 29·788 | 71·7 | 56·2 | W |
| 12 | 29·866 | 29·859 | 29·788 | 29·768 | 81·7 | 57·2 | E | 12 | 29·803 | 29·864 | 29·851 | 29·858 | 72·6 | 57·1 | E |
| 13 | 29·792 | 29·802 | 29·930 | 30·017 | 68·8 | 55·3 | SW | 13 | 29·768 | 29·741 | 29·766 | 29·833 | 64·8 | 54·1 | E |
| 14 | 30·077 | 30·106 | 30·080 | 30·029 | 67·9 | 50·0 | SSW | 14 | 29·875 | 29·943 | 29·937 | 29·933 | 67·4 | 53·3 | W |
| 15 | 29·960 | 29·974 | 29·958 | 29·985 | 67·7 | 55·4 | SW | 15 | 29·869 | 29·803 | 29·788 | 29·813 | 66·1 | 48·3 | SE |
| 16 | 30·028 | 30·065 | 30·064 | 30·049 | 70·1 | 54·1 | SW | 16 | 29·837 | 29·869 | 29·881 | 29·854 | 67·1 | 56·6 | W |
| 17 | 30·019 | 30·053 | 30·034 | 30·062 | 71·1 | 55·7 | W | 17 | 29·800 | 29·869 | 29·914 | 29·963 | 64·8 | 54·6 | WNW |
| 18 | 30·082 | 30·104 | 30·072 | 30·056 | 72·0 | 49·9 | WSW | 18 | 29·977 | 29·990 | 29·977 | 29·948 | 66·9 | 49·4 | SW |
| 19 | 29·981 | 29·915 | 29·840 | 29·820 | 72·0 | 56·7 | SSW | 19 | 29·849 | 29·776 | 29·685 | 29·608 | 59·1 | 52·7 | S |
| 20 | 29·747 | 29·748 | 29·740 | 29·795 | 68·7 | 54·1 | SW | 20 | 29·548 | 29·554 | 29·537 | 29·572 | 63·8 | 53·3 | W |
| 21 | 29·786 | 29·773 | 29·668 | 29·651 | 61·1 | 52·9 | S | 21 | 29·591 | 29·605 | 29·607 | 29·627 | 62·1 | 52·3 | W |
| 22 | 29·732 | 29·862 | 29·886 | 29·867 | 67·3 | 53·0 | W | 22 | 29·652 | 29·681 | 29·676 | 29·647 | 62·3 | 48·5 | NNW |
| 23 | 29·749 | 29·810 | 29·918 | 29·991 | 66·1 | 48·5 | W | 23 | 29·663 | 29·737 | 29·793 | 29·844 | 67·2 | 46·2 | WNW |
| 24 | 29·973 | 29·935 | 29·831 | 29·686 | 65·1 | 50·7 | SW | 24 | 29·807 | 29·731 | 29·578 | 29·535 | 58·1 | 50·0 | SSE |
| 25 | 29·593 | 29·424 | 29·558 | 29·743 | 64·1 | 53·3 | W | 25 | 29·585 | 29·682 | 29·691 | 29·745 | 61·9 | 49·9 | N |
| 26 | 29·796 | 29·860 | 29·921 | 29·984 | 61·2 | 51·0 | WNW | 26 | 29·777 | 29·819 | 29·881 | 29·926 | 59·9 | 49·9 | NW |
| 27 | 29·991 | 30·018 | 30·005 | 30·020 | 64·0 | 47·3 | NW | 27 | 29·936 | 29·948 | 29·941 | 29·957 | 62 6 | 49·3 | NW |
| 28 | 29·991 | 30·019 | 29·965 | 29·980 | 67·5 | 51·7 | NNW | 28 | 29·943 | 29·937 | 29·904 | 29·880 | 64·0 | 46·9 | WSW |
| 29 | 29·950 | 29·942 | 29·866 | 29·832 | 70·9 | 53·7 | SW | 29 | 29·793 | 29·743 | 29·627 | 29·533 | 58·4 | 53·4 | SSW |
| 30 | 29·753 | 29·721 | 29·708 | 29·682 | 66·0 | 54·1 | SW | 30 | 29·473 | 29·448 | 29·424 | 29·390 | 63·3 | 52·9 | W |

* No observation.

## JULY, 1900.

| | KEW. | | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer. | | | | Temperature. | | | | Barometer. | | | | Temperature. | | |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. |
| 1 | 29·588 | 29·633 | 29·687 | 29·682 | 66·1 | 56·5 | WSW | 1 | 29·362 | 29·402 | 29·433 | 29·447 | 63·4 | 52·2 | WNW |
| 2 | 29·647 | 29·648 | 29·598 | 29·611 | 63·6 | 55·4 | SW | 2 | 29·462 | 29·506 | 29·534 | 29·573 | 64·4 | 50·4 | W |
| 3 | 29·679 | 29·762 | 29·811 | 29·933 | 67·1 | 53·7 | SW | 3 | 29·617 | 29·718 | 29·844 | 29·950 | 63·4 | 52·3 | N |
| 4 | 30·022 | 30·114 | 30·109 | 30·129 | 70·0 | 51·2 | N | 4 | 29·992 | 30·012 | 29·964 | 29·884 | 58·4 | 49·8 | E |
| 5 | 30·072 | 30·047 | 29·967 | 29·976 | 74·4 | 54·7 | WSW | 5 | 29·815 | 29·841 | 29·847 | 29·789 | 61·4 | 52·2 | W |
| 6 | 29·910 | 29·957 | 29·979 | 29·999 | 65·1 | 54·0 | WNW | 6 | 29·765 | 29·812 | 29·923 | 30·056 | 60·9 | 48·9 | NW |
| 7 | 30·029 | 30·105 | 30·147 | 30·205 | 62·0 | 48·4 | N | 7 | 30·125 | 30·154 | 30·152 | 30·208 | 63·7 | 48·1 | N |
| 8 | 30·225 | 30·243 | 30·234 | 30·236 | 64·3 | 45·2 | N | 8 | 30·198 | 30·184 | 30·163 | 30·125 | 59·7 | 46·4 | W |
| 9 | 30·221 | 30·203 | 30·165 | 30·148 | 70·9 | 55·6 | W | 9 | 30·068 | 30·052 | 30·022 | 29·996 | 58·5 | 54·4 | W |
| 10 | 30·119 | 30·110 | 30·032 | 30·033 | 81·8 | 52·7 | W | 10 | 29·931 | 29·934 | 29·861 | 29·834 | 73·9 | 56·1 | WSW |
| 11 | 29·994 | 29·952 | 29·866 | 29·825 | 83·2 | 54·0 | SSE | 11 | 29·792 | 29·806 | 29·788 | 29·777 | 67·4 | 58·2 | WSW |
| 12 | 29·745 | 29·707 | 29·680 | 29·721 | 78·2 | 60·4 | ESE | 12 | 29·708 | 29·722 | 29·702 | 29·700 | 62·1 | 57·0 | W |
| 13 | 29·751 | 29·804 | 29·810 | 29·895 | 80·4 | 57·4 | SSW | 13 | 29·715 | 29·737 | 29·717 | 29·724 | 63·3 | 50·8 | NE |
| 14 | 29·904 | 29·933 | 29·936 | 30·018 | 75·2 | 59·0 | SW | 14 | 29·686 | 29·700 | 29·741 | 29·829 | 66·9 | 55·9 | W |
| 15 | 30·056 | 30·093 | 30·064 | 30·100 | 82·0 | 53·9 | SW | 15 | 29·909 | 29·988 | 30·009 | 30·025 | 68·1 | 54·0 | SW |
| 16 | 30·077 | 30·025 | 29·998 | 30·078 | 90·1 | 60·0 | S | 16 | 29·976 | 29·954 | 29·922 | 29·981 | 69·6 | 57·9 | WSW |
| 17 | 30·144 | 30·236 | 30·219 | 30·239 | 80·5 | 60·0 | NW | 17 | 30·037 | 30·109 | 30·122 | 30·111 | 64·5 | 57·3 | W |
| 18 | 30·227 | 30·196 | 30·101 | 30·095 | 83·5 | 56·4 | SSW | 18 | 30·070 | 30·042 | 29·982 | 30·007 | 72·2 | 61·2 | SW |
| 19 | 30·040 | 30·000 | 29·934 | 29·956 | 89·4 | 54·7 | SSW | 19 | 29·974 | 29·995 | 29·995 | 30·024 | 69·4 | 60·0 | WNW |
| 20 | 29·942 | 29·944 | 29·966 | 30·058 | 89·4 | 66·2 | SSE | 20 | 30·049 | 30·093 | 30·075 | 30·091 | 63·3 | 56·3 | ENE |
| 21 | 30·064 | 30·112 | 30·093 | 30·133 | 76·8 | 61·4 | SW | 21 | 30·054 | 30·060 | 30·045 | 30·040 | 57·8 | 54·2 | E |
| 22 | 30·116 | 30·128 | 30·086 | 30·106 | 77·8 | 62·7 | WNW | 22 | 30·044 | 30·056 | 30·014 | 30·034 | 70·5 | 54·3 | NNW |
| 23 | 30·104 | 30·107 | 30·057 | 30·061 | 82·7 | 64·7 | NNW | 23 | 30·022 | 30·018 | 29·938 | 29·808 | 65·1 | 57·3 | WSW |
| 24 | 30·047 | 30·040 | 29·979 | 29·960 | 86·0 | 62·3 | SSW | 24 | 29·867 | 29·895 | 29·872 | 29·825 | 66·1 | 59·9 | W |
| 25 | 29·917 | 29·903 | 29·837 | 29·883 | 89·3 | 60·1 | SW | 25 | 29·782 | 29·807 | 29·810 | 29·845 | 69·1 | 59·1 | WSW |
| 26 | 29·932 | 30·011 | 30·021 | 30·055 | 78·1 | 64·3 | NW | 26 | 29·893 | 29·964 | 30·000 | 30·057 | 65·8 | 54·9 | W |
| 27 | 30·049 | 30·017 | 29·947 | 29·852 | 77·9 | 61·2 | ENE | 27 | 30·047 | 30·029 | 29·965 | 29·944 | 68·9 | 50·3 | NW |
| 28 | 29·734 | 29·745 | 29·734 | 29·784 | 76·9 | 61·4 | SSW | 28 | 29·846 | 29·749 | 29·618 | 29·615 | 58·9 | 53·1 | E |
| 29 | 29·760 | 29·771 | 29·739 | 29·775 | 72·3 | 59·2 | SW | 29 | 29·585 | 29·565 | 29·548 | 29·556 | 61·9 | 55·3 | SW |
| 30 | 29·788 | 29·855 | 29·889 | 29·987 | 73·0 | 57·5 | W | 30 | 29·595 | 29·686 | 29·765 | 29·867 | 63·9 | 54·8 | W |
| 31 | 30·018 | 30·045 | 29·993 | 29·965 | 76·0 | 54·3 | WSW | 31 | 26·890 | 29·880 | 29·777 | 29·681 | 67·3 | 48·9 | SW |

## AUGUST, 1900.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 29·885 | 29·863 | 29·769 | 29·764 | 67·7 | 56·3 | S | 1 | 29·593 | 29·523 | 29·420 | 29·375 | 63·9 | 54·1 | SW |
| 2 | 29·728 | 29·760 | 29·766 | 29·796 | 71·0 | 55·0 | WSW | 2 | 29·296 | 29·385 | 29·485 | 29·530 | 62·1 | 54·0 | WNW |
| 3 | 29·663 | 29·411 | 29·281 | 29·313 | 67·1 | 52·3 | SSW | 3 | 29·474 | 29·437 | 29·476 | 29·581 | 60·5 | 51·3 | E |
| 4 | 29·529 | 29·689 | 29·773 | 29·825 | 63·5 | 50·2 | NW | 4 | 29·652 | 29·698 | 29·694 | 29·689 | 62·3 | 46·1 | NW |
| 5 | 29·802 | 29·764 | 29·613 | 29·570 | 62·7 | 48·9 | SSW | 5 | 29·623 | 29·548 | 29·474 | 29·485 | 57·7 | 47·1 | S |
| 6 | 29·594 | 29·558 | 29·267 | 29·811 | 63·1 | 51·0 | S | 6 | 29·445 | 29·375 | 29·255 | 29·211 | 58·3 | 51·9 | S |
| 7 | 29·457 | 29·559 | 29·590 | 29·669 | 65·1 | 53·9 | WSW | 7 | 29·261 | 29·404 | 29·561 | 29·670 | 57·2 | 53·1 | NNE |
| 8 | 29·721 | 29·881 | 29·953 | 29·995 | 63·7 | 52·5 | N | 8 | 29·769 | 29·883 | 29·905 | 29·900 | 58·4 | 49·2 | E |
| 9 | 29·926 | 29·849 | 29·598 | 29·598 | 60·2 | 51·9 | SSW | 9 | 29·832 | 29·746 | 29·689 | 29·731 | 55·8 | 46·9 | ENE |
| 10 | 29·779 | 29·918 | 30·083 | 30·228 | 62·1 | 53·7 | WNW | 10 | 29·811 | 29·959 | 30·041 | 30·145 | 64·9 | 51·1 | W |
| 11 | 30·286 | 30·338 | 30·320 | 30·346 | 70·7 | 49·8 | NW | 11 | 30·191 | 30·224 | 30·192 | 30·104 | 60·6 | 48·9 | WSW |
| 12 | 30·324 | 30·319 | 30·284 | 30·318 | 76·4 | 55·9 | WSW | 12 | 30·101 | 30·174 | 30·210 | 30·239 | 66·3 | 53·1 | WSW |
| 13 | 30·334 | 30·378 | 30·340 | 30·348 | 80·1 | 53·8 | W | 13 | 30·255 | 30·305 | 30·329 | 30·350 | 62·1 | 54·4 | W |
| 14 | 30·346 | 30·349 | 30·276 | 30·318 | 79·4 | 53·8 | N | 14 | 30·345 | 30·348 | 30·307 | 30·308 | 73·1 | 53·9 | W |
| 15 | 30·310 | 30·291 | 30·206 | 30·191 | 69·5 | 57·9 | ENE | 15 | 30·286 | 30·248 | 30·147 | 30·134 | 77·9 | 52·9 | NE |
| 16 | 30·139 | 30·106 | 30·028 | 30·022 | 74·8 | 58·0 | NE | 16 | 30·108 | 30·102 | 30·060 | 30·045 | 73·4 | 53·1 | W |
| 17 | 29·974 | 29·969 | 29·903 | 29·946 | 78·0 | 60·3 | N | 17 | 29·988 | 29·977 | 29·936 | 29·957 | 66·8 | 54·9 | W |
| 18 | 29·941 | 29·963 | 29·936 | 29·963 | 81·3 | 59·2 | E | 18 | 29·946 | 29·988 | 29·991 | 30·005 | 64·9 | 53·4 | NW |
| 19 | 29·943 | 29·946 | 29·877 | 29·872 | 76·0 | 56·4 | S | 19 | 29·981 | 29·990 | 29·936 | 29·917 | 56·5 | 51·9 | E |
| 20 | 29·817 | 29·812 | 29·750 | 29·736 | 74·0 | 54·9 | SW | 20 | 29·842 | 29·801 | 29·740 | 29·692 | 53·3 | 50·1 | E |
| 21 | 29·684 | 29·651 | 29·595 | 29·558 | 70·4 | 57·8 | S | 21 | 29·621 | 29·585 | 29·488 | 29·433 | 60·9 | 52·0 | E |
| 22 | 29·406 | 29·451 | 29·490 | 29·580 | 68·0 | 54·0 | SSW | 22 | 29·338 | 29·320 | 29·318 | 29·353 | 58·6 | 53·8 | E |
| 23 | 29·590 | 29·622 | 29·609 | 29·603 | 65·9 | 51·3 | SW | 23 | 29·398 | 29·469 | 29·526 | 29·640 | 60·3 | 49·9 | E |
| 24 | 29·641 | 29·693 | 29·715 | 29·792 | 70·2 | 52·1 | SW | 24 | 29·702 | 29·777 | 29·816 | 29·881 | 61·1 | 48·7 | E |
| 25 | 29·819 | 29·892 | 29·941 | 30·032 | 66·0 | 50·0 | N | 25 | 29·939 | 30·011 | 30·102 | 30·166 | 58·8 | 50·9 | ESE |
| 26 | 30·056 | 30·076 | 30·018 | 30·004 | 62·9 | 53·2 | NNE | 26 | 30·191 | 30·221 | 30·227 | 30·258 | 56·3 | 48·3 | E |
| 27 | 29·944 | 29·966 | 29·977 | 30·027 | 61·0 | 54·0 | NNE | 27 | 30·154 | 30·270 | 30·270 | 30·331 | 55·7 | 48·4 | E |
| 28 | 30·064 | 30·140 | 30·153 | 30·245 | 61·9 | 57·0 | N | 28 | 30·320 | 30·355 | 30·358 | 30·374 | 56·1 | 48·9 | ENE |
| 29 | 30·267 | 30·310 | 30·308 | 30·352 | 68·0 | 56·7 | NE | 29 | 30·360 | 30·369 | 30·330 | 30·335 | 59·9 | 49·9 | E |
| 30 | 30·354 | 30·375 | 30·344 | 30·349 | 66·1 | 51·3 | N | 30 | 30·316 | 30·297 | 30·216 | 30·172 | 66·9 | 48·8 | S |
| 31 | 30·318 | 30·299 | 30·189 | 30·150 | 72·0 | 46·3 | SSW | 31 | 30·044 | 29·935 | 29·871 | 29·931 | 61·9 | 55·9 | SW |

## SEPTEMBER, 1900.

| | KEW. | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer. | | | | Temperature. | | Direction of wind at noon. | | Barometer. | | | | Temperature. | | Direction of wind at noon |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | |
| 1 | 30·063 | 30·031 | 29·986 | 30·019 | 67·0 | 58·2 | SW | 1 | 29·912 | 29·909 | 29·864 | 29·889 | 60·4 | 52·1 | W |
| 2 | 30·010 | 30·057 | 30·104 | 30·223 | 61·5 | 50·8 | NW | 2 | 29·957 | 30·094 | 30·212 | 30·317 | 60·5 | 46·0 | N |
| 3 | 30·300 | 30·414 | 30·417 | 30·438 | 60·1 | 44·7 | NE | 3 | 30·339 | 30·364 | 30·356 | 30·367 | 56·6 | 39·2 | WNW |
| 4 | 30·421 | 30·419 | 30·332 | 30·326 | 63·7 | 41·9 | W | 4 | 30·321 | 30·306 | 30·238 | 30·203 | 58·0 | 50·1 | W |
| 5 | 30·300 | 30·277 | 30·189 | 30·188 | 68·0 | 44·0 | W | 5 | 30·140 | 30.121 | 30·052 | 30·049 | 60·9 | 52·8 | W |
| 6 | 30·192 | 30·194 | 30·120 | 30·105 | 71·0 | 43·3 | SW | 6 | 30·045 | 30·063 | 30·033 | 30·024 | 62·5 | 55·0 | W |
| 7 | 30·058 | 30·034 | 29·963 | 29·948 | 70·6 | 45·3 | W | 7 | 29·968 | 29·952 | 29·905 | 29 918 | 56·2 | 51·1 | WSW |
| 8 | 29·901 | 29·939 | 29·951 | 30·010 | 68·2 | 51·9 | N | 8 | 29·927 | 29.954 | 29·926 | 29·920 | 59·5 | 49·5 | W |
| 9 | 30·000 | 30·011 | 30·013 | 30·050 | 68·3 | 52·1 | WSW | 9 | 29·913 | 29·951 | 29·950 | 29·949 | 60·4 | 49·2 | W |
| 10 | 30·062 | 30·120 | 30·135 | 30 239 | 69·0 | 51·5 | W | 10 | 29·876 | 30·000 | 30·139 | 30·258 | 62·3 | 53·1 | WNW |
| 11 | 30·304 | 30·399 | 30·415 | 30·475 | 65·0 | 48·7 | N | 11 | 30·325 | 30·397 | 30·409 | 30·436 | 64·2 | 49·2 | W |
| 12 | 30·487 | 30·513 | 30·440 | 30·459 | 68·6 | 44·1 | N | 12 | 30·448 | 30·458 | 30·428 | 30·439 | 61·6 | 49·1 | W |
| 13 | 30·455 | 30·463 | 30·388 | 30·413 | 68·8 | 43·6 | NE | 13 | 30·432 | 30·435 | 30·362 | 30·368 | 67·8 | 41·9 | W |
| 14 | 30·376 | 30·390 | 30·305 | 30·261 | 65·2 | 50·9 | E | 14 | 30·341 | 30·337 | 30·232 | 30·209 | 68·3 | 42·6 | W |
| 15 | 30·185 | 30·176 | 30·095 | 30·112 | 70·5 | 55·2 | ENE | 15 | 30·152 | 30·119 | 30·015 | 30·028 | 67·8 | 43·7 | WNW |
| 16 | 30·077 | 30·095 | 30·068 | 30·119 | 79·4 | 58·0 | E | 16 | 30·013 | 30·034 | 30·017 | 30·046 | 61·5 | 49·3 | NW |
| 17 | 30·109 | 30·112 | 30·020 | 30·045 | 72·3 | 54·4 | S | 17 | 30·020 | 29·984 | 29·895 | 29·869 | 66·4 | 50·4 | E |
| 18 | 29·994 | 29·971 | 29·907 | 30·007 | 69·3 | 56·0 | SSW | 18 | 29·777 | 29·767 | 29·817 | 29·879 | 59·2 | 49·1 | W |
| 19 | 30·072 | 30·171 | 30·198 | 30·290 | 66·6 | 46·5 | N | 19 | 29·906 | 30·009 | 30·083 | 30·156 | * | 46·1 | W |
| 20 | 30·316 | 30·354 | 30·303 | 30·349 | 68·0 | 42·8 | SW | 20 | 30·134 | 30·056 | 29·980 | 30·067 | 59·7 | 47·3 | WSW |
| 21 | 30·345 | 30·350 | 30·270 | 30·269 | 70·9 | 42·8 | SW | 21 | 30·147 | 30·152 | 30·059 | 29·989 | 57·9 | 45·1 | WSW |
| 22 | 30·235 | 30·268 | 30·222 | 30·229 | 70·8 | 56·2 | WSW | 22 | 30·002 | 30·109 | 30·105 | 30 079 | 59·4 | 50·8 | WNW |
| 23 | 30·186 | 30·170 | 30·022 | 29·950 | 71·4 | 52·5 | SW | 23 | 29·983 | 29·890 | 29·705 | 29·507 | 61·3 | 50·2 | WSW |
| 24 | 29·777 | 29·725 | 29·732 | 29·829 | 69·0 | 50·0 | SW | 24 | 29·299 | 29·487 | 29·606 | 29·700 | 61·1 | 47·1 | W |
| 25 | 29·885 | 29·983 | 29·986 | 30·056 | 62·0 | 43·3 | NW | 25 | 29·746 | 29·752 | 29·706 | 29·670 | 53·8 | 44·0 | W |
| 26 | 30·024 | 30·056 | 29·977 | 29·864 | 64·0 | 46·3 | W | 26 | 29·791 | 29·835 | 29·499 | 29·225 | 59·4 | 42·3 | S |
| 27 | 29·675 | 29·607 | 29·573 | 29·570 | 60·3 | 56·0 | SSW | 27 | 29·156 | 29·191 | 29·259 | 29·370 | 57·6 | 51·9 | WSW |
| 28 | 29·562 | 29·626 | 29·687 | 29·796 | 61·9 | 52·0 | W | 28 | 29·490 | 29·619 | 29·644 | 29·657 | 53·9 | 48·6 | E |
| 29 | 29·846 | 29·888 | 29·830 | 29·806 | 63·8 | 45·9 | WSW | 29 | 29·629 | 29·587 | 29·509 | 29·386 | 56·4 | 49·8 | SW |
| 30 | 29·731 | 29·677 | 29·630 | 29·755 | 62·1 | 48·4 | SSW | 30 | 29·262 | 29·368 | 29·472 | 29·559 | 56·3 | 47·1 | W |

## OCTOBER, 1900.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 29·844 | 29·907 | 29·887 | 29·908 | 60·5 | 44·0 | SW | 1 | 29·567 | 29·588 | 29·599 | 29·624 | 52·1 | 45·9 | W |
| 2 | 29·865 | 29·848 | 29·771 | 29·767 | 63·1 | 48·1 | SW | 2 | 29·592 | 29·593 | 29·510 | 29·569 | 53·6 | 44·6 | S |
| 3 | 29·770 | 29·922 | 29·993 | 30·060 | 57·4 | 39·3 | WNW | 3 | 29·671 | 29·786 | 29·865 | 29·906 | 52·3 | 38·4 | W |
| 4 | 29·961 | 29·790 | 29·599 | 29·700 | 61·3 | 39·2 | SSE | 4 | 29·801 | 29·600 | 29·304 | 29·243 | 51·4 | 36·9 | E |
| 5 | 29·749 | 29·808 | 29·754 | 29·868 | 59·1 | 48·9 | SW | 5 | 29·307 | 29·391 | 29·375 | 29·448 | 52·2 | 43·1 | SW |
| 6 | 29·939 | 30·002 | 30·022 | 30·104 | 64·3 | 52·9 | SW | 6 | 29·536 | 29·584 | 29·508 | 29·704 | 50·8 | 41·3 | WSW |
| 7 | 30·155 | 30·229 | 30·231 | 30·257 | 65·7 | 49·3 | SW | 7 | 29·790 | 29·757 | 29·798 | 29·843 | 60·2 | 40·4 | WSW |
| 8 | 30·210 | 30·191 | 30·196 | 30·235 | 70·1 | 47·0 | SW | 8 | 29·814 | 29·845 | 29·864 | 29·956 | 57·7 | 53·0 | WSW |
| 9 | 30·168 | 30·160 | 30·090 | 30·078 | 69·1 | 49·9 | WSW | 9 | 29·968 | 29·964 | 29·916 | 29·935 | 53·9 | 49·2 | SW |
| 10 | 29·982 | 30·096 | 30·112 | 30·194 | 60·7 | 44·2 | WNW | 10 | 29·937 | 30·019 | 30·053 | 30·067 | 52·4 | 44·9 | NW |
| 11 | 30·183 | 30·179 | 30·076 | 30·082 | 56·9 | 39·1 | WNW | 11 | 29·980 | 29·915 | 29·815 | 29·851 | 52·1 | 44·5 | WSW |
| 12 | 30·046 | 30·061 | 30·007 | 30·023 | 58·0 | 40·4 | WNW | 12 | 29·873 | 29·858 | 29·776 | 29·668 | 50·5 | 43·6 | W |
| 13 | 29·923 | 29·838 | 29·721 | 29·692 | 55·3 | 45·6 | WSW | 13 | 29·457 | 29·359 | 29·374 | 29·392 | 49·9 | 37·8 | WNW |
| 14 | 29·685 | 29·708 | 29·765 | 29·803 | 49·2 | 38·6 | W | 14 | 29·414 | 29·546 | 29·574 | 29·570 | 43·3 | 36·1 | NW |
| 15 | 29·776 | 29·817 | 29·832 | 29·879 | 51·6 | 39·0 | WNW | 15 | 29·604 | 29·678 | 29·715 | 29·768 | 48·9 | 38·9 | WNW |
| 16 | 29·890 | 29·948 | 29·905 | 29·848 | 51·0 | 36·6 | W | 16 | 29·778 | 29·807 | 29·750 | 29·691 | 47·4 | 31·3 | SE |
| 17 | 29·762 | 29·713 | 29·713 | 29·760 | 61·0 | 48·0 | W | 17 | 29·610 | 29·592 | 29·609 | 29·686 | 48·4 | 42·2 | ESE |
| 18 | 29·784 | 29·851 | 29·904 | 30·016 | 55·1 | 47·9 | NW | 18 | 29·767 | 29·913 | 30·023 | 30·113 | 55·1 | 45·9 | WNW |
| 19 | 30·073 | 30·146 | 30·152 | 30·197 | 53·8 | 45·8 | NNE | 19 | 30·160 | 30·209 | 30·200 | 30·227 | 51·8 | 45·4 | E |
| 20 | 30·183 | 30·184 | 30·144 | 30·176 | 50·1 | 43·0 | N | 20 | 30·211 | 30·228 | 30·222 | 30·284 | 50·4 | 44·1 | NE |
| 21 | 30·183 | 30·250 | 30·310 | 30·432 | 49·5 | 37·8 | N | 21 | 30·307 | 30·409 | 30·465 | 30·517 | 48·3 | 36·1 | NE |
| 22 | 30·495 | 30·552 | 30·499 | 30·488 | 49·7 | 37·7 | N | 22 | 30·468 | 30·457 | 30·364 | 30·325 | 52·3 | 38·5 | W |
| 23 | 30·385 | 30·350 | 30·291 | 30·312 | 56·8 | 41·9 | W | 23 | 30·301 | 30·284 | 30·240 | 30·209 | 55·3 | 51·1 | W |
| 24 | 30·278 | 30·280 | 30·173 | 30·082 | 58·1 | 47·7 | W | 24 | 30·133 | 30·071 | 29·974 | 29·872 | 56·3 | 48·0 | W |
| 25 | 29·910 | 29·787 | 29·659 | 29·637 | 57·0 | 45·9 | SW | 25 | 29·622 | 29·509 | 29·356 | 29·311 | 48·4 | 38·8 | WNW |
| 26 | 29·514 | 29·286 | 29·271 | 29·318 | 49·9 | 38·6 | WSW | 26 | 29·170 | 29·188 | 29·182 | 29·210 | 45·1 | 35·2 | N |
| 27 | 29·323 | 29·399 | 29·559 | 29·693 | 52·6 | 38·7 | W | 27 | 29·267 | 29·396 | 29·446 | 29·522 | 50·1 | 39·4 | N |
| 28 | 29·773 | 29·856 | 29·746 | 29·541 | 55·0 | 37·3 | WSW | 28 | 29·537 | 29·559 | 29·516 | 29·398 | 46·4 | 37·1 | W |
| 29 | 29·590 | 29·675 | 29·691 | 29·768 | 55·6 | 48·7 | SW | 29 | 29·357 | 29·387 | 29·418 | 29·508 | 48·5 | 36·9 | W |
| 30 | 29·785 | 29·859 | 29·884 | 29·931 | 54·0 | 46·6 | WSW | 30 | 29·587 | 29·699 | 29·763 | 29·833 | 49·4 | 37·1 | WNW |
| 31 | 29·954 | 29 961 | 29·889 | 29·852 | 62·1 | 51·9 | S | 31 | 29·804 | 29·771 | 29·698 | 29·649 | 52·1 | 39.3 | E |

* No observation.

## NOVEMBER, 1900.

| KEW. | | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BAROMETER. | | | | TEMPERATURE. | | Direction of wind at noon. | | BAROMETER. | | | | TEMPERATURE. | | Direction of wind at noon. |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | |
| 1 | 29·810 | 29·819 | 29·819 | 29·903 | 59·9 | 53·1 | SW | 1 | 29·586 | 29·645 | 29·765 | 29·930 | 57·4 | 50·4 | W |
| 2 | 30·017 | 30·150 | 30·183 | 30·224 | 55·9 | 52·7 | N | 2 | 30·009 | 30·091 | 30·096 | 30·112 | 55·3 | 48·3 | SW |
| 3 | 30·213 | 30·210 | 30·150 | 30·130 | 55·9 | 51·0 | N | 3 | 30·071 | 30·037 | 29·967 | 29·959 | 55·2 | 51·8 | SSW |
| 4 | 30·075 | 30·050 | 29·948 | 29·877 | 53·4 | 49·4 | S | 4 | 29·906 | 29·886 | 29·826 | 29·811 | 52·1 | 47·2 | W |
| 5 | 29·855 | 29·852 | 29·763 | 29·703 | 56·8 | 50·2 | SW | 5 | 29·763 | 29·716 | 29·606 | 29·533 | 50·4 | 45·4 | SE |
| 6 | 29·591 | 29·496 | 29·390 | 29·280 | 57·0 | 50·9 | SSE | 6 | 29·458 | 29·423 | 29·354 | 29·281 | 51·2 | 46·1 | E |
| 7 | 29·205 | 29·394 | 29·550 | 29·709 | 52·3 | 46·9 | SW | 7 | 29·237 | 29·296 | 29·403 | 29·549 | 49·7 | 42·5 | N |
| 8 | 29·853 | 29·943 | 29·822 | 29·734 | 53·0 | 40·3 | SW | 8 | 29·565 | 29·360 | 29·215 | 29·280 | 50·1 | 38·3 | SW |
| 9 | 29·679 | 29·688 | 29·670 | 29·670 | 53·6 | 41·7 | WSW | 9 | 29·249 | 29·301 | 29·282 | 29·275 | 45·1 | 37·3 | WSW |
| 10 | 29·651 | 29·687 | 29·660 | 29·670 | 48·0 | 31·9 | WSW | 10 | 29·209 | 29·251 | 29·334 | 29·459 | 45·1 | 37·9 | W |
| 11 | 29·730 | 29·832 | 29·881 | 29·922 | 45·3 | 27·3 | SW | 11 | 29·573 | 29·670 | 29·662 | 29·677 | 41·7 | 35·4 | WSW |
| 12 | 29·865 | 29·826 | 29·695 | 29·660 | 53·0 | 34·7 | S | 12 | 29·630 | 29·528 | 29·385 | 29·346 | 41·3 | 38·0 | E |
| 13 | 29·606 | 29·567 | 29·546 | 29·570 | 56·3 | 46·0 | SW | 13 | 29·245 | 29·252 | 29·235 | 29·307 | 48·0 | 39·6 | SW |
| 14 | 29·563 | 29·600 | 29·689 | 29·751 | 50·7 | 40·6 | W | 14 | 29·382 | 29·567 | 29·610 | 29·509 | 48·1 | 42·3 | NNW |
| 15 | 29·655 | 29·372 | 29·283 | 29·259 | 52·9 | 40·2 | SW | 15 | 29·226 | 29·053 | 29·017 | 29·041 | 44·4 | 40·4 | E |
| 16 | 29·146 | 29·141 | 29·233 | 29·433 | 48·1 | 41·9 | E | 16 | 29·172 | 29·372 | 29·578 | 29·778 | 46·9 | 40·1 | NE |
| 17 | 29·559 | 29·706 | 29·809 | 29·963 | 48·1 | 41·9 | N | 17 | 29·874 | 30·026 | 30·156 | 30·293 | 44·9 | 40·4 | NNE |
| 18 | 30·046 | 30·175 | 30·256 | 30·342 | 47·0 | 40·7 | N | 18 | 30·353 | 30·442 | 30·456 | 30·458 | 42·9 | 34·0 | WNW |
| 19 | 30·321 | 30·286 | 30·212 | 30·182 | 44·8 | 39·8 | NNE | 19 | 30·409 | 30·386 | 30·327 | 30·307 | 37·8 | 27·3 | S |
| 20 | 30·098 | 30·043 | 29·935 | 29·882 | 45·1 | 38·0 | NNE | 20 | 30·257 | 30·221 | 30·093 | 30·021 | 38·9 | 31·9 | E |
| 21 | 29·803 | 29·779 | 29·714 | 29·705 | 45·9 | 41·4 | NNE | 21 | 29·916 | 29·861 | 29·782 | 29·820 | 42·7 | 36·3 | E |
| 22 | 29·721 | 29·771 | 29·765 | 29·772 | 46·1 | 38·8 | W | 22 | 29·783 | 29·771 | 29·697 | 29·621 | 45·1 | 30·9 | W |
| 23 | 29·763 | 29·762 | 29·673 | 29·699 | 47·5 | 29·2 | S | 23 | 29·557 | 29·567 | 29·575 | 29·623 | 43·1 | 38·3 | W |
| 24 | 29·707 | 29·725 | 29·652 | 29·540 | 47·7 | 36·3 | E | 24 | 29·596 | 29·561 | 29·455 | 29·390 | 43·6 | 40·1 | SE |
| 25 | 29·385 | 29·413 | 29·470 | 29·558 | 53·0 | 40·5 | W | 25 | 29·325 | 29·387 | 29·457 | 29·530 | 44·0 | 39·2 | ENE |
| 26 | 29·644 | 29·698 | 29·643 | 29·515 | 50·0 | 38·8 | SW | 26 | 29·528 | 29·507 | 29·384 | 29·239 | 46·8 | 43·8 | SSE |
| 27 | 29·476 | 29·586 | 29·532 | 29·442 | 50·8 | 40·9 | SW | 27 | 29·219 | 29·338 | 29·375 | 29·365 | 44·9 | 37·9 | SW |
| 28 | 29·277 | 29·176 | 29·143 | 29·195 | 47·7 | 41·0 | E | 28 | 29·302 | 29·311 | 29·267 | 29·318 | 45·4 | 34·8 | E |
| 29 | 29·114 | 29·171 | 29·337 | 29·514 | 47·7 | 43·6 | ENE | 29 | 29·382 | 29·506 | 29·544 | 29·643 | 45·5 | 43·8 | E |
| 30 | 29·574 | 29·657 | 29·685 | 29·722 | 46·2 | 42·1 | N | 30 | 29·717 | 29·745 | 29·754 | 29·752 | 45·1 | 41·1 | E |

## DECEMBER, 1900.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 29·696 | 29·686 | 29·675 | 29·718 | 44·0 | 40·2 | E | 1 | 29·728 | 29·730 | 29·711 | 29·729 | 44·5 | 40·7 | E |
| 2 | 29·734 | 29·804 | 29·835 | 29·897 | 43·3 | 40·6 | E | 2 | 29·739 | 29·780 | 29·789 | 29·770 | 44·5 | 41·3 | S |
| 3 | 29·910 | 29·893 | 29·750 | 29·510 | 52·9 | 40·3 | S | 3 | 29·686 | 29·604 | 29·422 | 29·219 | 44·2 | 40·3 | WSW |
| 4 | 29·428 | 29·575 | 29·631 | 29·609 | 54·3 | 49·5 | W | 4 | 29·273 | 29·411 | 29·399 | 29·383 | 42·2 | 37·1 | W |
| 5 | 29·596 | 29·583 | 29·451 | 29·367 | 56·1 | 49·9 | SSE | 5 | 29·391 | 29·403 | 29·324 | 29·311 | 41·1 | 38·4 | ENE |
| 6 | 29·694 | 29·723 | 29·544 | 29·625 | 54·1 | 45·5 | SW | 6 | 29·377 | 29·381 | 29·377 | 29·483 | 40·5 | 37·9 | NE |
| 7 | 29·819 | 30·002 | 30·119 | 30·206 | 50·8 | 37·0 | W | 7 | 29·697 | 29·863 | 29·910 | 29·838 | 44·9 | 38·1 | S |
| 8 | 30·182 | 30·169 | 30·112 | 30·069 | 52·7 | 37·3 | SSW | 8 | 29·606 | 29·602 | 29·516 | 29·518 | 55·1 | 44·4 | SW |
| 9 | 30·008 | 30·036 | 30·120 | 30·233 | 53·6 | 44·7 | W | 9 | 29·556 | 29·672 | 29·745 | 29·878 | 49·1 | 44·2 | WSW |
| 10 | 30·299 | 30·385 | 30·359 | 30·318 | 46·4 | 37·0 | SW | 10 | 30·006 | 30·063 | 29·987 | 29·781 | 47·1 | 42·4 | SW |
| 11 | 30·236 | 30·173 | 30·085 | 30·061 | 52·1 | 38·3 | SW | 11 | 29·663 | 29·644 | 29·583 | 29·454 | 51·4 | 44·1 | WSW |
| 12 | 30·037 | 30·147 | 30·133 | 30·078 | 55·1 | 51·0 | SW | 12 | 29·611 | 29·749 | 29·700 | 29·605 | 53·3 | 49·6 | WSW |
| 13 | 30·007 | 29·987 | 30·024 | 30·194 | 53·2 | 41·7 | WSW | 13 | 29·538 | 29·563 | 29·659 | 29·783 | 53·1 | 41·9 | WSW |
| 14 | 30·268 | 30·340 | 30·307 | 30·287 | 50·8 | 41·4 | SW | 14 | 29·522 | 29·805 | 29·784 | 29·749 | 51·0 | 41·8 | SW |
| 15 | 30·209 | 30·127 | 30·149 | 30·309 | 52·8 | 43·7 | SW | 15 | 29·669 | 29·670 | 29·711 | 29·918 | 48·1 | 43·9 | WSW |
| 16 | 30·405 | 30·494 | 30·467 | 30·475 | 48·5 | 39·2 | SW | 16 | 30·062 | 30·134 | 30·104 | 30·074 | 50·1 | 45·6 | SW |
| 17 | 30·409 | 30·343 | 30·207 | 30·112 | 47·9 | 35·4 | SSW | 17 | 29·991 | 29·892 | 29·784 | 29·690 | 50·1 | 47·4 | SW |
| 18 | 30·051 | 30·050 | 30·015 | 29·939 | 51·2 | 43·0 | SSW | 18 | 29·648 | 29·824 | 29·859 | 29·844 | 49·2 | 39·4 | WSW |
| 19 | 29·986 | 30·169 | 30·178 | 30·150 | 50·2 | 37·3 | SW | 19 | 29·784 | 29·812 | 29·760 | 29·590 | 46·9 | 39·4 | WSW |
| 20 | 29·949 | 29·820 | 29·631 | 29·530 | 53·7 | 43·6 | S | 20 | 29·302 | 29·151 | 28·830 | 28·437 | 54·3 | 43·3 | SW |
| 21 | 29·574 | 29·736 | 29·826 | 29·890 | 51·1 | 39·4 | WSW | 21 | 28·788 | 29·184 | 29·518 | 29·691 | 48·1 | 37·4 | W |
| 22 | 30·012 | 30·076 | 29·985 | 29·916 | 40·2 | 33·4 | W | 22 | 29·757 | 29·798 | 29·761 | 29·756 | 43·2 | 37·5 | WSW |
| 23 | 29·940 | 29·964 | 29·965 | 29·933 | 36·9 | 32·1 | W | 23 | 29·767 | 29·770 | 29·674 | 29·708 | 45·1 | 39·5 | S |
| 24 | 29·980 | 30·081 | 30·109 | 30·103 | 44·2 | 31·0 | SSE | 24 | 29·778 | 29·790 | 29·654 | 29·568 | 50·1 | 40·1 | SW |
| 25 | 30·059 | 30·040 | 29·973 | 29·885 | 52·0 | 44·2 | SSW | 25 | 29·535 | 29·505 | 29·379 | 29·334 | 53·3 | 48·9 | SSW |
| 26 | 29·802 | 29·874 | 29·872 | 29·823 | 51·2 | 44·1 | SW | 26 | 29·479 | 29·512 | 29·554 | 29·575 | 49·1 | 41·3 | SW |
| 27 | 29·610 | 29·462 | 29·377 | 29·231 | 51·2 | 44·7 | S | 27 | 29·476 | 29·365 | 29·177 | 28·914 | 45·2 | 40·4 | E |
| 28 | 29·045 | 28·930 | 29·189 | 29·483 | 52·9 | 41·0 | W | 28 | 28·596 | 28·704 | 28·962 | 29·262 | 45·7 | 40·1 | NW |
| 29 | 29·621 | 29·711 | 29·726 | 29·743 | 44·7 | 37·0 | W | 29 | 29·415 | 29·526 | 29·578 | 29·536 | 42·1 | 35·6 | W |
| 30 | 29·674 | 29·602 | 29·324 | 28·945 | 51·7 | 41·4 | S | 30 | 29·363 | 29·384 | 29·348 | 29·461 | 42·5 | 33·9 | ENE |
| 31 | 28·928 | 29·387 | 29·751 | 29·951 | 44·0 | 37·9 | NNE | 31 | 29·638 | 29·826 | 29·886 | 29·803 | 42·5 | 38·6 | ENE |

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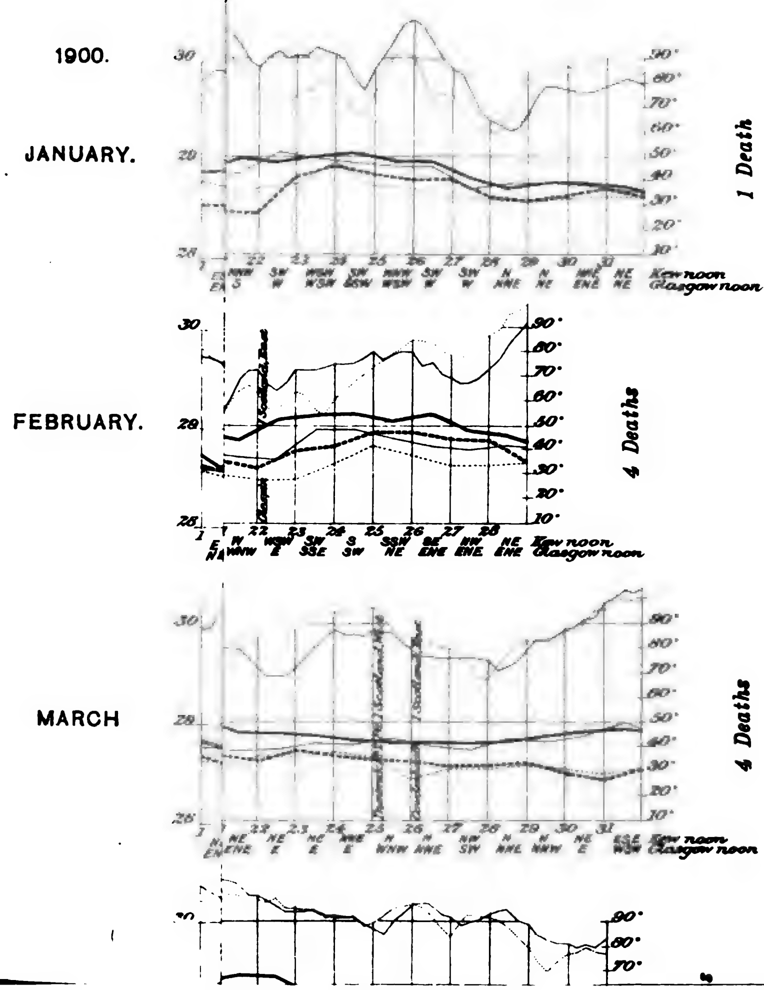
ND.



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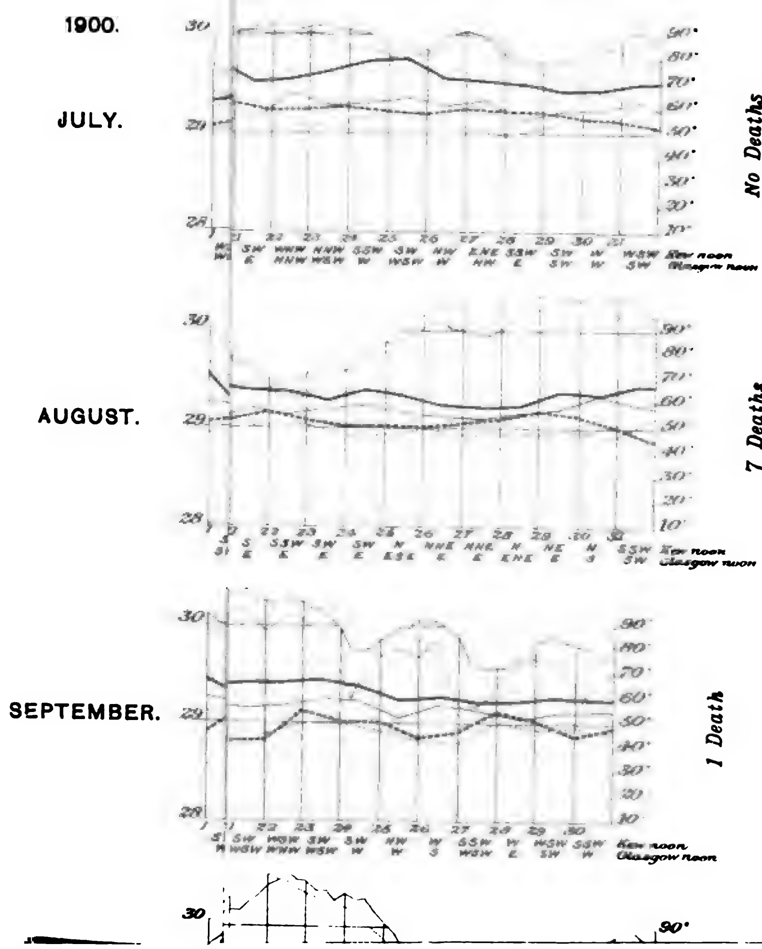
...ETHER WITH THE EXPLOSIONS
...ND



# INDEX TO VOL. XXI.

EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used:—

C.—Chesterfield and Midland Counties Institution of Engineers.
M.—Midland Institute of Mining, Civil and Mechanical Engineers.
S.—Mining Institute of Scotland.
N.E.—North of England Institute of Mining and Mechanical Engineers.
N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.
S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.